

Fishery Data Series No. 96-14

Chinook Salmon Research on the Unuk River, 1994

by

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July 1996

Alaska Department of Fish and Game

Division of Sport Fish



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Weights and measures (metric)		General		Mathematics, statistics, fisheries	
centimeter	cm	All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.	alternate hypothesis	H_A
deciliter	dL	All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.	base of natural logarithm	e
gram	g	and	&	catch per unit effort	CPUE
hectare	ha	at	@	coefficient of variation	CV
kilogram	kg	Compass directions:		common test statistics	F, t, χ^2 , etc.
kilometer	km			confidence interval	C.I.
liter	L			correlation coefficient	R (multiple)
meter	m	east	E	correlation coefficient	r (simple)
metric ton	mt	north	N	covariance	cov
milliliter	ml	south	S	degree (angular or temperature)	°
millimeter	mm	west	W	degrees of freedom	df
Weights and measures (English)		Copyright	©	divided by	+ or / (in equations)
cubic feet per second	ft ³ /s	Corporate suffixes:		equals	=
foot	ft	Company	Co.	expected value	E
gallon	gal	Corporation	Corp.	fork length	FL
inch	in	Incorporated	Inc.	greater than	>
mile	mi	Limited	Ltd.	greater than or equal to	≥
ounce	oz.	et alii (and other people)	et al.	harvest per unit effort	HPUE
pound	lb	et cetera (and so forth)	etc.	less than	<
quart	qt	exempli gratia (for example)	e.g.,	less than or equal to	≤
yard	yd	id est (that is)	i.e.,	logarithm (natural)	ln
Spell out acre and ton.		latitude or longitude	lat. or long.	logarithm (base 10)	log
Time and temperature		monetary symbols (U.S.)	\$, ¢	logarithm (specify base)	log ₂ , etc.
day	d	months (tables and figures): first three letters	Jan,...,Dec	mid-eye-to-fork	MEF
degrees Celsius	°C	number (before a number)	# (e.g., #10)	minute (angular)	'
degrees Fahrenheit	°F	pounds (after a number)	# (e.g., 10#)	multiplied by	x
hour (spell out for 24-hour clock)	h	registered trademark	®	not significant	NS
minute	min	trademark	™	null hypothesis	H_0
second	s	United States (adjective)	U.S.	percent	%
Spell out year, month, and week.		United States of America (noun)	USA	probability	P
Physics and chemistry		U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)	probability of a type I error (rejection of the null hypothesis when true)	α
all atomic symbols				probability of a type II error (acceptance of the null hypothesis when false)	β
alternating current	AC			second (angular)	"
ampere	A			standard deviation	SD
calorie	cal			standard error	SE
direct current	DC			standard length	SL
hertz	Hz			total length	TL
horsepower	hp			variance	Var
hydrogen ion activity	pH				
parts per million	ppm				
parts per thousand	ppt, ‰				
volts	V				
watts	W				

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July 1996

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-10, Job No. S-1-8.

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This document should be cited as:

Pahlke, Keith A., Scott A. McPherson, and Robert P. Marshall. 1995. Chinook salmon Research on the Unuk River, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 96-14, Anchorage.

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ABSTRACT

The distribution and abundance of large chinook salmon *Oncorhynchus tshawytscha* that returned to spawn in the Unuk River in 1994 were estimated by using radio telemetry and a mark-recapture experiment. Age, sex, and length compositions were estimated for the immigration, and juvenile chinook salmon from the 1992 and 1993 brood years were captured for coded wire tagging to enable estimation of future harvests.

Set gillnets were used to capture 169 immigrant chinook salmon ≥ 660 mm in (mid-eye to fork) length during June and July, 1994. One hundred sixty-one (161) fish were marked with spaghetti tags and opercle punches, and 109 of these fish also had radio transmitters inserted into their stomachs; 94 of the fish with radio transmitters were tracked to spawning locations. An estimated 17.4% (SE = 4.2%) of the fish returned to Canada, and 82.6% (SE = 8.6%) spawned in U.S. tributaries and mainstem waters.

During August, 313 chinook salmon ≥ 660 mm in length were captured at spawning sites and inspected for tags; 10 of these fish had been previously marked. A modified Petersen model ($n_1 = 161$, $n_2 = 313$, $m_2 = 10$) estimated that 4,623 (SE = 1,266) chinook salmon ≥ 660 mm in length immigrated to the Unuk River in 1994. Peak survey counts in August totaled 711 large chinook, about 15% of the estimated inriver run. Age and length composition of the immigration was estimated using a combination of the gillnet and spawning ground samples to remove bias. An estimated 9% of the immigration were age 1.1, 13% age 1.2, 28% age 1.3, 46% age 1.4, and 2% age 1.5.

During October 1993, 13,959 juveniles from the 1992 brood year were tagged with coded wire tags, and another 2,642 smolt from the 1992 brood were tagged in May of 1994. In October 1994, 20,542 fish from the 1993 brood year were tagged.

Key words: Chinook salmon, *Oncorhynchus tshawytscha*, Unuk River, radio telemetry, mark-recapture, escapement, spawning distribution, abundance, coded wire tags, Behm Canal.

INTRODUCTION

In the mid- to late 1970s, it became apparent that chinook salmon *Oncorhynchus tshawytscha* stocks were depressed in the Southeast Alaska region, relative to historical levels of production (Kissner 1982). The Alaska Department of Fish and Game (ADF&G) developed a structured rebuilding program in 1981 to rebuild Southeast chinook salmon stocks over a 15-year period (roughly three life cycles; ADF&G 1981). The rebuilding program has been evaluated, in part, by monitoring trends in indices of escapement for important stocks.

Stocks in eleven river systems in Southeast Alaska are surveyed annually: the Situk, Alsek, Chilkat, Taku, King Salmon, Stikine, Unuk, Chickamin, Blossom, and Keta rivers, and Andrew Creek. Of these eleven index systems, total escapement at the Situk, Chilkat, Taku, and King Salmon rivers and at Andrew Creek has been only estimated.

The Unuk, Chickamin, Blossom, and Keta rivers flow through Misty Fiords National Monument/Wilderness into Behm Canal, a narrow saltwater passage east of Ketchikan (Figure 1). They constitute the four index systems for the chinook salmon program in southern Southeast Alaska (Pahlke 1994) and are collectively referred to as the Behm Canal chinook systems. Between 1986 and 1989, survey counts reached peak levels in the Behm Canal systems, then began a steady decline. By 1993, concern for the status and health of these stocks became a priority issue.

The Unuk River (the largest system) was selected for a study to validate the ongoing index program in the area.

The objectives of the study were:

- (1) to detect all spawning areas in the Unuk River drainage which receive $\geq 5\%$ of the large (≥ 660 mm MEF length) immigrant chinook salmon;

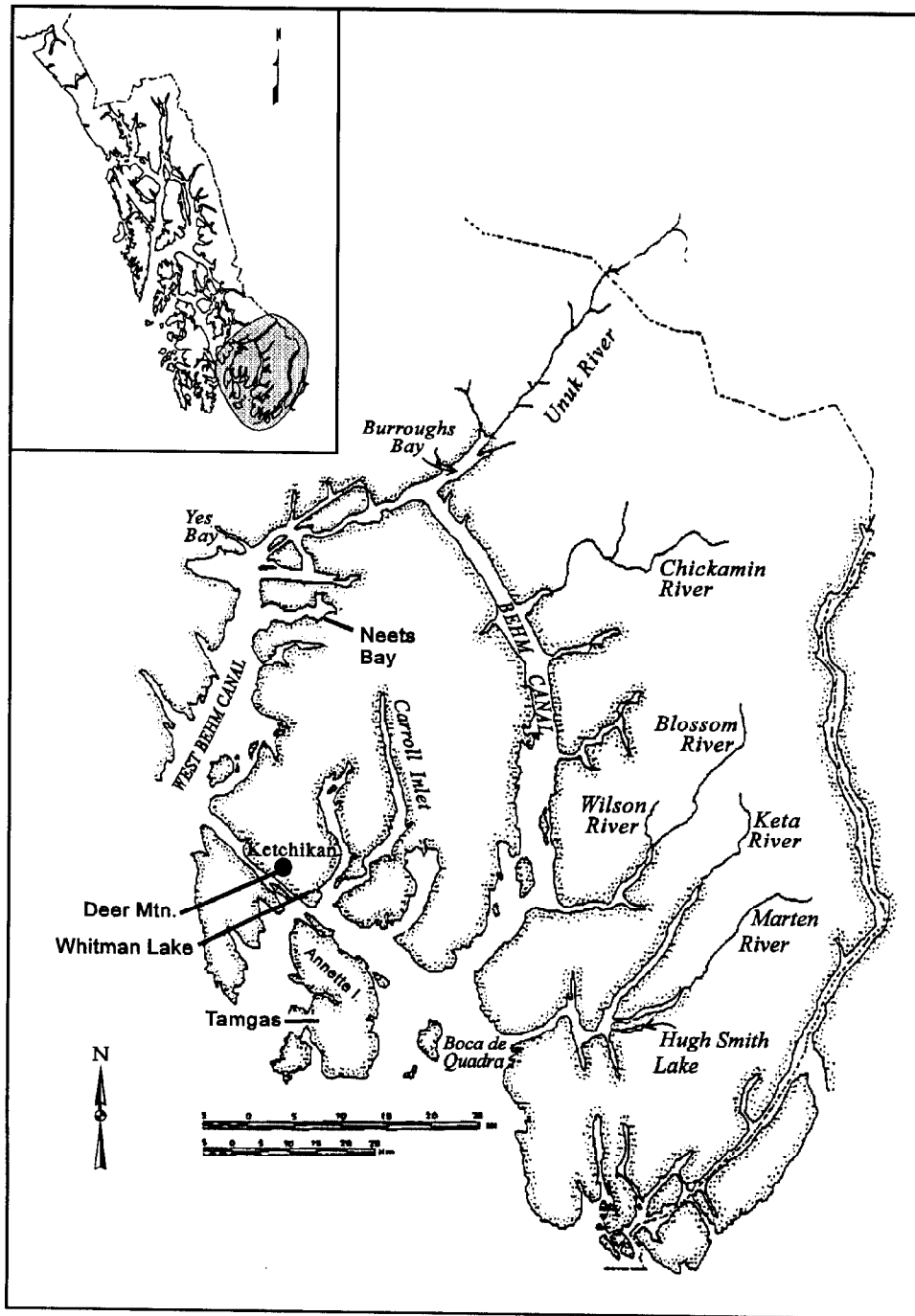


Figure 1.—Behm Canal area and location of major chinook systems and hatcheries.

- (2) to estimate the abundance of large spawning chinook in the Unuk River;
- (3) to estimate the age, sex, and length compositions of chinook salmon in the Unuk River; and
- (4) to mark a sufficient number of juvenile chinook salmon from the 1992 and 1993 brood years with coded wire tags (CWTs) to permit estimates of future harvests in sport and commercial fisheries.

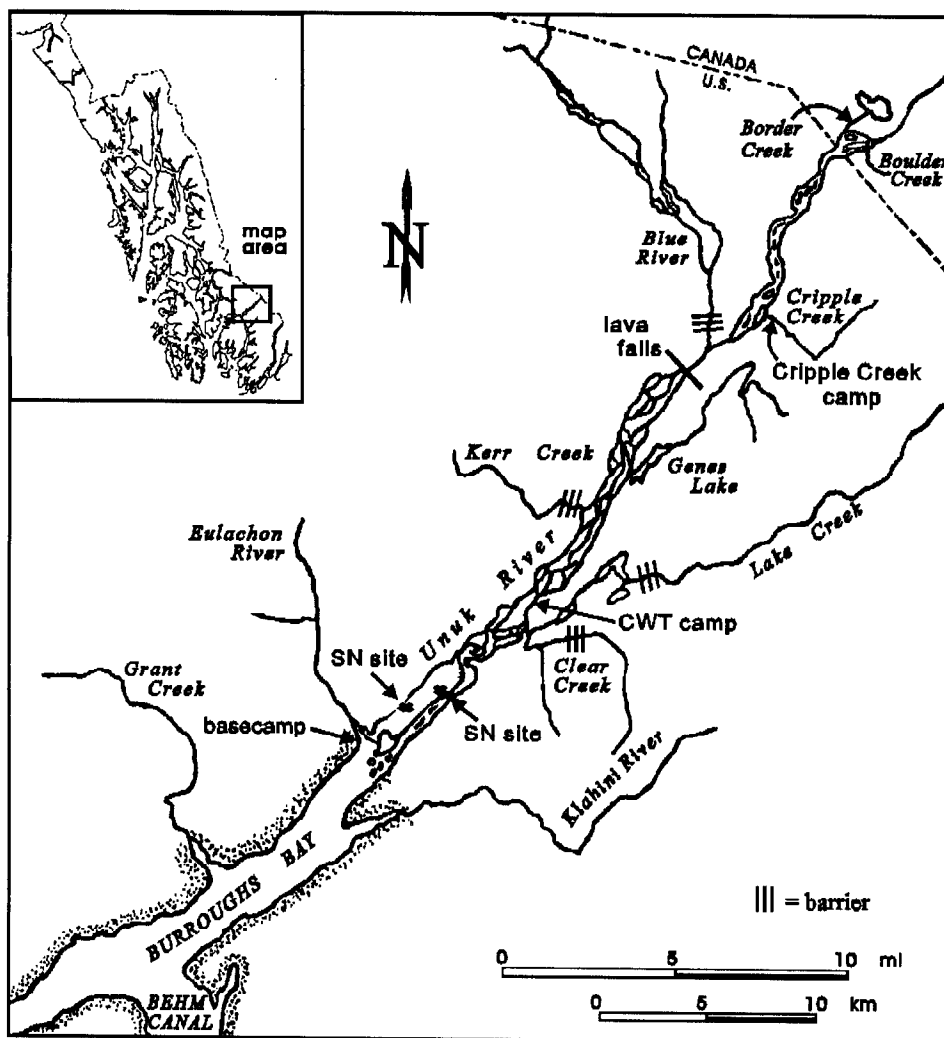


Figure 2.—Unuk River area, showing major tributaries, barriers to fish migration and location of ADF&G research sites.

Results from this study will: (1) help determine if current survey index areas represent the important spawning areas used in 1994; (2) allow a benchmark index survey-to-abundance expansion factor to be estimated; (3) permit escapements from specific brood years to be estimated; and (4) permit harvest patterns and exploitation rates in sampled fisheries in Southeast Alaska to be estimated.

STUDY AREA

The Unuk River drainage encompasses an area of approximately 3,885 km² and is the fourth or fifth

largest producer of king salmon in Southeast Alaska (Pahlke 1994). It originates in a heavily glaciated area of northern British Columbia and flows 129 km to Burroughs Bay, 85 km northeast of Ketchikan, Alaska; the lower 39 km of the river lies in Alaska (Figure 2).

Most chinook salmon spawn in U.S. tributaries, including the Eulachon River (19%), Cripple Creek (41%), Genes Lake Creek (28%), Clear Creek (8%), Lake Creek (2%), and Kerr Creek (2%) (percentages based on aerial survey counts; Table 1; Pahlke 1994). Since 1981, the sum of these index counts has been assumed to represent

Table 1.—Distribution of spawning chinook salmon among index areas of the Unuk River for years when all index areas were surveyed.

Year	Cripple Creek	%	Genes Lake Creek	%	Eulachon Creek	%	Clear Creek	%	Lake Creek	%	Kerr Creek	%	Total	Border Creek ^a
1978	394	36	374	34	218	20	85	8	20	2	15	1	1,106	
1979	363	63	101	18	48	8	14	2	30	5	20	3	576	
1980	748	74	122	12	95	9	28	3	5	0	18	2	1,016	
1981	324	44	112	15	196	27	54	7	20	3	25	3	731	
1982	538	40	329	24	384	28	24	2	48	4	28	2	1,351	
1983	459	41	338	30	288	26	24	2	12	1	4	0	1,125	
1984	644	35	647	35	350	19	113	6	32	2	51	3	1,837	
1985	284	24	553	47	275	23	37	3	22	2	13	1	1,184	
1986	532	25	838	39	486	23	183	9	25	1	62	3	2,126	
1987	860	44	398	20	520	26	107	5	37	2	51	3	1,973	
1988	1,068	61	154	9	146	8	292	17	60	3	26	1	1,746	17
1989	351	31	302	26	298	26	128	11	27	2	43	4	1,149	
1990	86	15	284	48	81	14	103	17	26	4	11	2	591	26
1991	358	55	123	19	43	7	96	15	23	4	12	2	655	108
1992	327	37	360	41	57	7	69	8	31	4	30	3	874	123
1993	448	42	330	31	132	12	137	13	8	0	13	1	1,068	143
Avg.	487	41	335	28	226	19	93	8	27	2	26	2	1,194	83
1994	161	23	300	42	52	7	128	18	18	3	52	7	711	42

^a Border Creek not included in index total.

62.5% of the total annual escapement to the Unuk River (Pahlke 1994).

Knowledge of the migration routes and run timing of Unuk and Chickamin River chinook salmon has been compiled by Pahlke (1995). The stocks rear primarily in the inside waters of southern and central Southeast Alaska and are available to harvest by Alaskan fisheries over much of their ocean residence. With the assumption that past index surveys counted 62.5% of the escapement, Pahlke (1995) estimated that exploitation rates for Unuk River chinook salmon from five brood years, 1982–1986, ranged from 29% to 42%.

The present index escapement goal for Unuk River chinook salmon is 875 fish \geq 660 mm MEF length (McPherson and Carlile *in press*).

METHODS

The research objectives to estimate abundance and distribution of immigrating chinook salmon relied on “marking” fish with radio transmitters and uniquely numbered tags as they traversed the lower Unuk River to upstream spawning sites.

Sampling effort was held reasonably constant across the temporal span of the migration. As the immigration waned, sampling for marks and age composition began at spawning sites. In addition, we captured young chinook salmon for coded wire tagging during spring 1993 and fall 1994 to permit a future estimation of contribution rates to fisheries.

Set gillnets were fished at two locations on the lower Unuk River between May 27 and July 31 to capture adult chinook salmon (Figure 3). One site was located approximately 1 mile up the north channel, or “Johnson Slough,” and the other approximately 2 miles up the south channel, or “mainstem,” of the Unuk River. These two sites were well below all known spawning areas, with the exception of the Eulachon River. Prior to May 27, other locations on the lower river were fished with both drift and set gillnets, but no safe drift gillnet sites were found.

Fish were captured in set gillnets 100 feet long and 18 feet deep, of 7.5-inch stretch mesh. One net was fished approximately 7 hours per day at the Johnson Slough site, and two nets at the

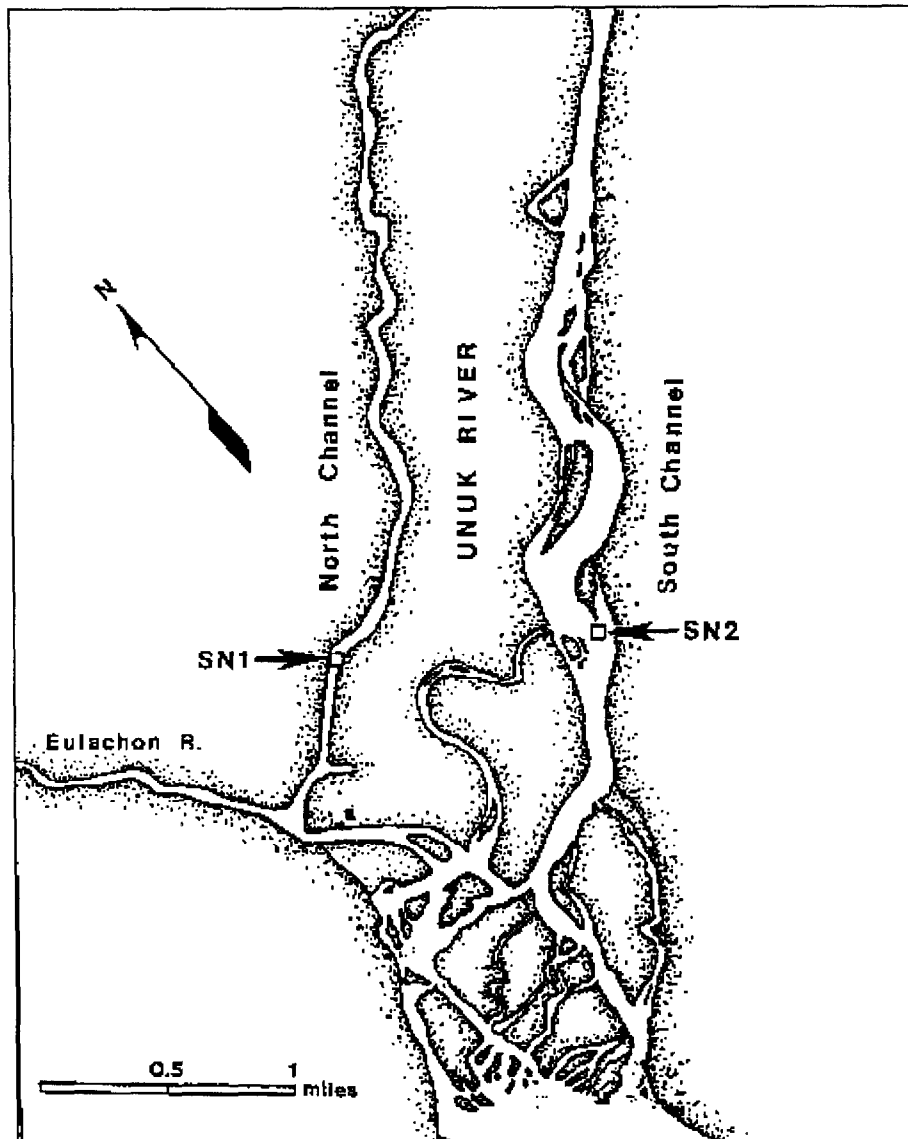


Figure 3.—Locations of setnet sites on the lower Unuk River, 1994.

mainstem site were fished approximately 7 hours per day each. Nets were set between 0800 hr and 1000 hr. At the Johnson Slough site, the net crossed about half the river, and at the mainstem site the combined nets were fished in a 'V' shape that covered less than one-quarter of the river.

Both sites were fished daily unless high water or manpower shortages occurred. The nets were watched continuously, and a fish was removed from the net as soon as it was observed. If fishing time was lost due to entanglements, snags, cleaning the net, etc., the lost time (processing

time) was added on to the end of the day to bring fishing time to 7 hours per net.

Captured chinook salmon were placed in a box filled with water, quickly untangled or cut from the net, tagged, scale sampled, and their length and sex recorded during a visual examination (Johnson et al., 1993). Captured fish were classified as 'large' if their mid-eye to fork length (MEF) was ≥ 660 mm, and 'small' if their MEF was < 660 mm (Pahlke 1994). Fish were judged to be 'bright' or 'dark' based on external appearance, and the presence or absence of sea

lice (*Lepeophtheirus* spp.) was noted. General health and appearance of the fish was recorded, including injuries from handling or predators.

Initially, every large healthy chinook salmon had a 30-31 MHz Advanced Telemetry Systems (ATS) radio transmitter esophageally inserted into its stomach (Eiler 1990), and had a uniquely numbered spaghetti tag attached just behind the dorsal fin. However, since capture rates were greater than expected, a smaller proportion of the chinook salmon captured during the latter half of the project were tagged with radio transmitters. Each spaghetti tag was threaded over a solid core of 40-pound monofilament fishing line which was threaded through the dorsal musculature of the fish and then crimped to itself with metal leader sleeves (Johnson et al. 1993). The upper portion (dorsal side) of the left operculum on each fish was given a ¼-inch diameter paper punch as a secondary mark. The frequency of each radio transmitter was checked immediately after the fish was released to verify it was operating correctly and to note any deviations from the listed frequency.

DISTRIBUTION OF SPAWNING

Assumptions of the experiment to estimate spawning distributions include: a) fish were captured for radio-tracking in proportion to abundance during the immigration, b) tagging did not change the destination (fate) of a fish; and c) fates of radio-tracked fish are accurately determined. The first assumption will be true if fishing effort and catchability were constant for all “stocks” (fish spawning in the same area) in the immigration (stocks might be characterized by their age composition and immigration timing). Catchability would presumably vary with river conditions. Thus, sampling effort was held as constant as practically possible during the immigration. The river stage (height) was recorded for comparison to catch rates at the gillnet sites. Contingency table analysis was used to test the assumption of similar migratory timing for the stocks, as noted below.

Beginning June 20, an attempt was made to locate each radio transmitter at least once a week from

boat or by airplane or helicopter as the size of the search area increased. The location of each tag was recorded by river mile from the mouth of the river or tributary. Transmitters used in this study were equipped with motion (mortality) sensors that doubled the pulse rate to 2 pulses per second following 3 to 4 h of inactivity. Subsequent movement reset the transmitter to the normal mode. Signals from radio-tagged fish were recorded as either normal or mortality mode (Eiler 1990, Bendock and Alexandersdottir 1992, Johnson et al. 1993).

At the conclusion of the tracking surveys, each radio-tagged fish was assigned one of five possible fates (Table 2; Johnson et al. 1993).

The proportion of large (660 mm and larger) chinook salmon spawning in each area was estimated

$$P_a = \frac{\sum_{t=1}^y \left(\frac{N_t}{n_t} \right) r_{a,t}}{\sum_{a=1}^x \sum_{t=1}^y \left(\frac{N_t}{n_t} \right) r_{a,t}} \quad (1)$$

where

$r_{a,t}$ = the number of large fish tagged with radios in period t that were tracked to and assumed to spawn in area a ,

N_t = the number of large fish captured in gillnets in period t , and

n_t = the number of large fish radio-tagged in period t .

Period (t) refers to distinct spans of time when the tagging fraction was constant. Transmitters assigned to fates not associated with successful spawning are ignored in computing P_a , so that the sum of the estimated proportions equals one.

The standard error of P_a was estimated using the bootstrap. In each period, n_t new samples were drawn from all assigned fates using the empirical distribution of the data, and new values of P_a computed. Bias corrected and accelerated (BCA) 95% confidence intervals for the estimated proportions were calculated from bootstrap samples (Efron and Tibshirani 1993), since the

Table 2.—Criteria used to assign fates to radio-tagged chinook salmon.

Fate code	Fate and criteria
1	Probable spawning in a tributary: a chinook salmon whose radio transmitter was tracked into a tributary, and remained in or was tracked downstream from that location. When a transmitter was tracked to more than one tributary, the last tributary was assumed to be the spawning location.
2	Mortality or regurgitation: a chinook salmon whose radio transmitter either did not advance upstream after tagging, or stopped in the mainstem Unuk River and broadcast in the mortality mode (perhaps intermittently) over at least 4 weeks, and never tracked to a lower location in the river.
3	Probable spawning in the mainstem: a chinook salmon whose radio transmitter was tracked upstream (first observation, if the highest observed, was not in the mortality mode), observed in a mode other than the mortality mode near its highest observed location, then observed in a downstream location.
4	Unknown: a chinook salmon whose radio transmitter was rarely located (one or two weeks, never in a tributary), and/or does not fit into any of the other 4 categories. These tracking histories were typically uninformative, or suggestive of more than one possible fate.

assumption of normality was clearly inappropriate for the smaller estimated proportions.

ABUNDANCE

The number of large chinook salmon in the Unuk River escapement was estimated from a two-event mark-recapture experiment. Fish captured by gillnet in the lower river and marked with spaghetti tags were included in event 1, and fish were inspected for marks on the spawning grounds for event 2. During event 2, fish were captured with dip nets and spears at seven spawning ground sites (Figure 2). The population was assumed to be closed during the study from August 6 through August 30.

Double-sampling on the spawning grounds was prevented by punching a hole in the lower (ventral) portion of the operculum of live fish and slashing sampled carcasses. The length and sex of each fish was recorded if possible, as well as the presence or absence of spaghetti tags, opercule punches, and adipose finclips. Five scales were collected from each fish for age analysis.

The validity of the (assumed closed-population) experiment rests on several assumptions: (a) that

every fish has an equal probability of being marked in event 1, *or* that every fish has an equal probability of being captured in event 2, *or* that marked fish mix completely with unmarked fish; (b) *both* recruitment and “death” (emigration) do not occur between sampling events; (c) marking does not affect catchability (or mortality) of the fish; (d) fish do not lose their marks between sample events; (e) all recovered marks are reported; and that (f) double sampling does not occur (Seber 1982, Bernard and Hansen 1992).

The first two assumptions must be carefully considered because of the spatial-temporal “range” present in this mark-recapture study. Assumption (a) implies that tagging must occur in proportion to abundance during immigration, or, if it does not, that no difference in age composition and immigration timing occurs between stocks bound for different spawning locations, since mixing does not occur in time and between recovery areas. Assumption (a) also implies that sampling is not size-selective. Assumption (b) suggests tagging across the immigration, because deaths occur between sampling events.

A 2x2 contingency table (chi-square statistic) was used to test the hypothesis ($\alpha = 0.05$) that recovery rates for fish marked with radio transmitters and spaghetti tags were equal; if they were, data for both tag-types were combined to estimate abundance. If recovery rates differed by mark type, a simple unstratified Petersen model might not be appropriate, since radio transmitters were inserted at higher rates on fish captured early in the migration. A similar test was used to determine if fish captured at the mainstem and Johnson slough tagging sites were bound for upper (Cripple and Border Creeks, and Canada), middle (Genes Lake and Kerr Creeks) and lower (Eulachon R., Clear and Lake Creeks) Unuk River spawning sites at equal rates. If they were, tagging data for the two sites were combined.

To provide evidence that assumption (a) was met, contingency table analysis was used to test the hypothesis ($\alpha = 0.05$) that fish sampled in upper, middle and lower spawning sites were marked at similar rates. If this hypothesis was accepted, a simple Petersen model was used to estimate abundance; otherwise a stratified Petersen model (Darroch 1961, Seber 1982, Chapter 11) was employed. Also, contingency table analysis was used to determine if fish marked early and late in the immigration traveled at similar rates to spawning sites in the upper (Cripple and Border Creeks, and Canada) and lower (Eulachon R., Clear and Lake Creeks) Unuk River. If this hypothesis was rejected, migratory timing of the stocks differed and rational for stratifying the marking event by time was demonstrable. The possibility of selective sampling was also investigated, since assumption (a) could be violated if sampling rate varied according to the size (or sex) of the fish. The hypothesis that fish of different sizes were captured with equal probability was tested with a Kolmogorov-Smirnov (K-S) 2-sample test (Bernard and Hansen 1992). Sex selection was tested using a 2x2 contingency table. If apparent, the abundance estimation procedures could be stratified by ages (age .3 versus age .4 and .5) and/or by sex.

Recruitment of untagged fish into the population was unlikely (assumption b), because gillnetting

operations spanned the immigration and continued without large interruption. We assume tagged and untagged fish experience the same mortality (assumption c) due to natural causes, unless unusual numbers of radio tagged fish died or were lost. Thus, estimates are germane to the time of tagging, rather than to recapture. To minimize effects of tag loss, all marked fish received a dorsal opercle punch which cannot be lost. Similarly, technicians inspect all fish captured on the spawning grounds for marks (assumption e), and double sampling was prevented by placement of a ventral opercle punch (assumption f).

AGE, SEX, AND LENGTH COMPOSITION OF ESCAPEMENT:

All fish captured in the gillnet and spawning ground surveys were sampled for scales to enable age determination (Olsen 1995). Proportions by age or by sex in gillnet and spawning grounds samples were estimated by

$$\hat{p}_i = \frac{n_i}{n} \quad (2)$$

$$V[\hat{p}_i] = \frac{\hat{p}_i(1 - \hat{p}_i)}{n - 1} \quad (3)$$

where p_i = the proportion in the population in group i,

n_i = the number in the sample of group I,

and

n = the sample size.

The age composition of chinook captured in the two lower river gillnets was compared using a chi-square test, prior to combining these samples. The test was also conducted for the different spawning areas. The age composition of the combined gillnet samples was compared with the age composition from the pooled spawning grounds using another chi-square test.

We found bias evident in both the gillnet and spawning grounds samples for estimating the age composition of the total escapement. The gillnet sample was biased toward large fish of both sexes

and the spawning grounds sample was biased towards females. To estimate age composition of the total escapement, we used a combination of gillnet and spawning grounds samples in a series of steps (Appendix E).

In summary, we (1) estimated the number of large fish of each sex from the sex composition of large fish in the gillnet sample applied to the estimate of large fish from the mark-recapture experiment, (2) estimated the age compositions of large male and females by pooling the large fish, by sex, from both samples, (3) applied those age compositions to the estimated abundance of large males and females, and (4) estimated the number of small males from the proportion of small males in the spawning grounds sample and the estimated abundance of large males.

Estimates of mean length at age and its variance was calculated by standard normal procedures.

CONTRIBUTIONS TO FISHERIES FROM THE 1992 AND 1993 BROOD YEARS

Chinook salmon smolt from the 1992 brood year were captured from May 5 to May 23, 1994 using a rotary screw trap (Elliott and Bernard 1994) and baited minnow traps (Pahlke 1995). Juvenile chinook salmon from the 1993 brood year were captured with baited minnow traps from October 5 through November 1, 1994. All captured fish were marked with CWTs and adipose finclips using the methods described in Hubartt and Kissner (1987). Tags will be recovered in various sport and commercial fisheries and the fraction of a brood year that has been tagged will be estimated from sampling returning adults for age and CWTs on the spawning grounds from 1995 through 1999 (Pahlke 1995).

RESULTS

One hundred sixty-nine (169) large (age 1.3 and older) and 15 small chinook salmon were captured in the lower Unuk River between May 16 and July 31, 1994 (Table 3, Appendices A1, A2). Setnet effort was maintained at 7 hours per day, with two nets at the mainstem site and one net at Johnson Slough, although several days were

Table 3.—Catch of large chinook salmon on the Unuk River in 1994, and numbers with radio transmitters inserted or marked only with spaghetti tags, by tagging site and period (period 1 was May 16 through July 1, and period 2 was July 2 through July 31, 1994).

	Mainstem site		Johnson Slough site		Total
	Period 1	Period 2	Period 1	Period 2	
Catch	51	67	13	38	169
Radio tags	48	31	12	18	109
Spaghetti tags only	0	32	1	19	52

not sampled (Figure 4; Appendices C1 and C2). Catch rates ranged from 0 to 2 fish/net/hr, but exceeded 0.7 only once, on July 12. The date of 50% cumulative catch was July 2 at the mainstem site (Figure 5). Highest catches occurred on July 12, when 19 large chinook were captured. Four large fish died in the nets and four escaped without being tagged. The remaining 161 fish were marked with spaghetti tags and upper opercle punches, and 109 of these also had radio transmitters inserted into their stomachs. The sex ratio of large chinook salmon caught in the gillnets was approximately equal (84 females, 77 males).

Initially, each large healthy chinook salmon captured was tagged with a radio transmitter. By late June, it became apparent that we would capture more fish than we had radio transmitters so, beginning on July 2, every other fish was tagged with a transmitter. Small chinook were released without any tags. In addition, 318 chum *O. keta*, 14 sockeye *O. nerka*, and 26 pink salmon *O. gorbuscha* were captured and released.

DISTRIBUTION OF SPAWNING

Of the 109 fish marked with radio transmitters, 94 (86.2%) were successfully tracked to spawning areas in the U.S. or above the border into Canada (Table 4). The 15 remaining transmitters were either regurgitated, lost because a fish died before spawning, never found, or tracked in a way that

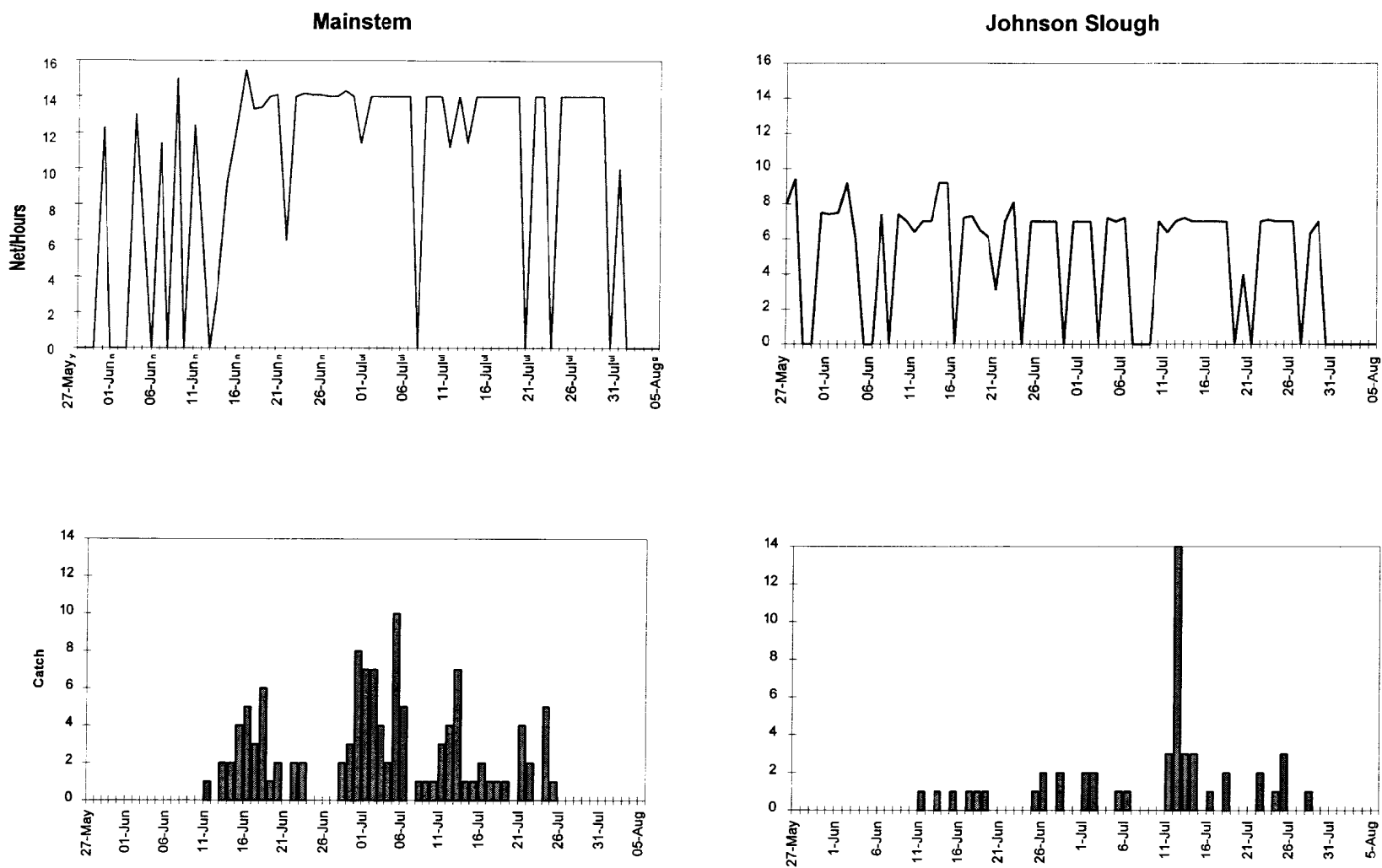


Figure 4.—Setnet effort (net hours), catch of large chinook, and catch/net/hour, by date and location, Unuk River, 1994.

Cumulative Catch Unuk River 1994

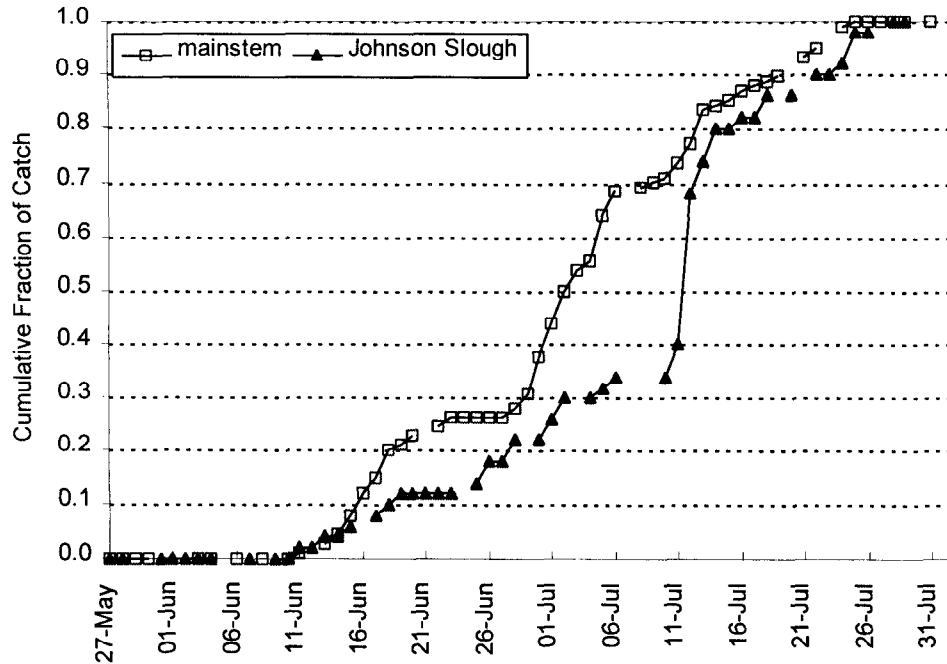


Figure 5.—Cumulative catch of large chinook salmon by date and capture site, Unuk River, 1994.

Table 4.—Summary of fates assigned to radio transmitters inserted in large chinook salmon by tagging period and site, and estimated percentages spawning by area, Unuk River, 1994.

Assigned fate	Radio tagged						Estimated proportion spawning	Bootstrap (%)		
	Period 1			Period 2				SE	LCI	UCI
	Site 1	Site 2	Total	Site 1	Site 2	Total				
Spawning:										
Canada	8	1	9	4	1	5	13.8	3.6	7.6	22.3
Border Cr.	1	0	1	2	0	2	3.6	2.1	0.7	10.2
Cripple Cr.	13	7	20	10	5	15	36.2	5.2	26.5	46.9
Genes Lake Cr.	8	2	10	3	5	8	18.8	4.2	12.1	28.4
Kerr Cr.	2	1	3	1	0	1	3.6	1.8	0.8	8.9
Clear and Lake Cr.	3	1	4	5	2	7	13.1	3.7	6.8	21.8
Eulachon River	2	0	2	2	3	5	8.7	3.2	3.6	16.4
Mainstem Unuk	1	0	1	0	1	1	2.2	1.6	0	8.9
Subtotal	38	12	50	27	17	44				
Mortality/regurgitation	6	0	6	1	1	2				
Unknown	4	0	4	3	0	3				
	48	12	60	31	18	49				

Period 1 = May 16–July 1; period 2 = July 2–July 31.

Site 1 = Mainstem site; site 2 = Johnson Slough site.

defined assignment of a fate (Appendix B). On August 12, a radio-tracking survey of the Klahini and Chickamin rivers was conducted for frequencies not previously located on the Unuk River, but none were found.

Based on the radio-tracking results, the estimated proportions of large chinook salmon spawning in each area of the Unuk River were: Eulachon River 8.7% (SE = 3.2%), Clear/Lake Creeks 13.1% (SE = 3.7%), Kerr Creek 3.6% (SE = 1.8%), Genes Lake Creek 18.8% (SE = 4.2%), Cripple Creek 36.2% (SE = 5.2%), Border Creek 3.6% (SE = 2.1%) and Canada 13.8% (SE = 3.6%), and the mainstem Unuk River (USA) 2.2% (SE = 1.6%). Bootstrap confidence intervals for the proportions spawning in each area were asymmetric for the areas with small contributions (Table 4).

ABUNDANCE

Three hundred thirteen (313) large chinook salmon were examined for marks on the spawning grounds, and 10 marked fish were recovered (Table 5; Appendix D1). The probability of recapturing spaghetti and radio-tagged fish was not significantly different ($\chi^2 = 0.01$, df = 1, P = 0.92; Table 6), indicating both types of tags could be pooled.

The distribution of fish radio-tracked from the Johnson Slough site was not significantly different from that of fish tracked from the mainstem site ($\chi^2 = 0.74$, df = 2, P = 0.69; Table 7), so tags from each site were also pooled. There was no significant difference between the distribution of fish tagged in Period 1 (May 16–July 1) and Period 2 (July 1–July 31) ($\chi^2 = 3.58$, df = 2, P = 0.17; Table 8) indicating similar migratory timing for the stocks.

Finally, the probability of recovering a marked fish in the lower (Eulachon, Lake, and Clear creeks; 0.039), middle (Genes Lake and Kerr creeks 0.035), and upper tributaries (Cripple and Border creeks, Canada; 0.026) was not significantly different ($\chi^2 = 0.37$ df = 2, P = 0.83; Table 9). Chapman's modified Petersen model (n1 = 161, n2 = 313, m2 = 10) could therefore be

Table 5.—Numbers of marked and unmarked chinook salmon sampled during spawning ground surveys, by size and location, Unuk River, 1994.

Location	Captures				Recaptures ^a	
	Large		Small		Large	
	M	F	M	F	Spag.	Radio
Border Cr.	6	13	1	0	0	1
Cripple Cr.	26	109	12	0	2	1
Genes Lake Cr.	12	24	13	0	0	1
Kerr Cr.	5	16	2	0	1	0
Clear and Lake Cr.	29	52	5	1	0	3
Eulachon R.	6	15	4	0	0	1
Total	84	229	37	1	3	7

^a Also included under captures.

Table 6.—Number of fish marked with spaghetti tags and radio tags that were recovered, and not recovered, in spawning ground surveys, Unuk River, 1994.

	Radio	Spaghetti	Total
Recovered	7	3	10
Not recovered	104	47	151
Total released	111	50	161
Recovery rate	0.063	0.060	0.062

Degrees of freedom: 1

Chi squared = 0.01, P = 0.92

H₀: Recovery rate of radio tags = recovery rate of spaghetti tags.

Accept H₀

used to estimate the number of large chinook salmon in the escapement to the Unuk River.

Not surprisingly, large females were captured more frequently than large males (229 females versus 84 males) in the escapement samples. This result is likely related to the observation (Paul Kissner, 1985) that female chinook salmon tend to die on their redds, while males tend to drift downstream after spawning. This sexual trait can cause size-selective sampling if females tend to be larger than males.

Length distributions of fish marked in event 1 and recovered in event 2 were not significantly different (KS tests, P = 0.21; Figure 6). However, length distributions of fish captured in event 1 and

Table 7.—Distribution of radio-tagged fish into lower, middle and upper spawning areas of the Unuk River, by tagging site, 1994.

	Lower	Middle	Upper
Johnson Slough	6	8	14
Mainstem site	12	14	38

$\chi^2 = 0.74$, $P = 0.69$

Lower area = Eulachon R., Clear and Lake creeks.

Middle area = Genes Lake and Kerr creeks.

Upper area = Cripple, Border creeks and Canada.

Table 8.—Distribution of radio-tagged fish into lower, middle, and upper spawning areas of the Unuk River, by tagging period, 1994.

	Lower	Middle	Upper
Period 1	6	13	30
Period 2	12	9	22

$\chi^2 = 3.58$, $P = 0.17$

Period 1 = May 16–July 1; period 2 = July 2–July 31.

Table 9.—Numbers of large chinook salmon marked (with spaghetti tags or radio tags) and not marked, in surveys of upper, middle and lower spawning areas of the Unuk River, 1994.

	Lower	Middle	Upper
Marked	4	2	4
Unmarked	98	55	150

$\chi^2 = 0.37$, $P = 0.83$

event 2 were different (KS test, $P < 0.001$; Figure 6). These tests suggest size selectivity during event 1, and that only fish sampled during event 2 should be used to estimate the age, sex and length compositions (Bernard and Hansen 1992). However, since there were only 10 recaptures, the power of the first hypothesis test is very low. Some size selectivity probably occurred in event 2 due to the selection for somewhat larger (see below) female carcasses. Thus, the experiment could be stratified by sex (or size) if sample sizes were large. However, since only 10 marked fish were recovered this was not possible.

Although 2 of 10 fish sampled in the spawning ground surveys had lost their primary (numbered) tag (Appendix D1), tag loss is not a factor, since fish did not lose their secondary mark. The estimated abundance was 4,623 fish ($SE = 1,266$). Confidence intervals for the estimated abundance were calculated using the bootstrap percentile method (Efron and Tibshirani 1993). The 95% bootstrap confidence limits were 2,992 and 9,425.

AGE, SEX, AND LENGTH COMPOSITIONS

Sex, length and scale samples were collected from 169 chinook salmon during gillnetting in the lower river. Ages could be determined for 143 fish, and sex was estimated for 161. Dominant age classes were 1.3 for males and 1.4 for females (Table 10); gillnet samples were 48% male and 52% female. As expected, small fish were scarce in the large-mesh gillnet catches. Length and sex were recorded for every fish but reported only for fish of known age (Table 11). Lengths from all fish were used in analysis of length distributions. Lengths ranged from 460 mm to 1,000 mm.

Three hundred seventy-eight (378) fish were examined during spawning ground sampling, and scale samples were obtained from 351 individuals. Ages could be determined for 302 fish, sex was estimated for 313 fish, and length was recorded for 290 fish. With three exceptions, all sampled fish spent 1 year in fresh water and the dominant ages were 1.3 and 1.4 for males and 1.4 for females (Table 12). Lengths ranged from 330 mm to 1,015 mm (Table 13). The sample was heavily biased towards females; 73% were female and 27% were male. Since sampling was strongly biased towards females, composition estimates for the escapement could not be obtained by simply combining the samples for each sex.

The age composition estimated from methodology described in Appendix E indicates that the escapement comprised 8.9% ($SE = 2.1\%$) age -1.1 fish, 13.3 % ($SE = 2.7\%$) age -1.2 fish, 28.4% ($SE = 2.3\%$) age -1.3 fish, 46.4% ($SE = 3.4\%$) age - 1.4 fish and 2.1 % ($SE = 0.7\%$) age -1.5 fish (Table 14, Appendix E1). Males constituted 58.2% ($SE = 4.6\%$) and females 41.8% ($SE = 4.6\%$) of the run.

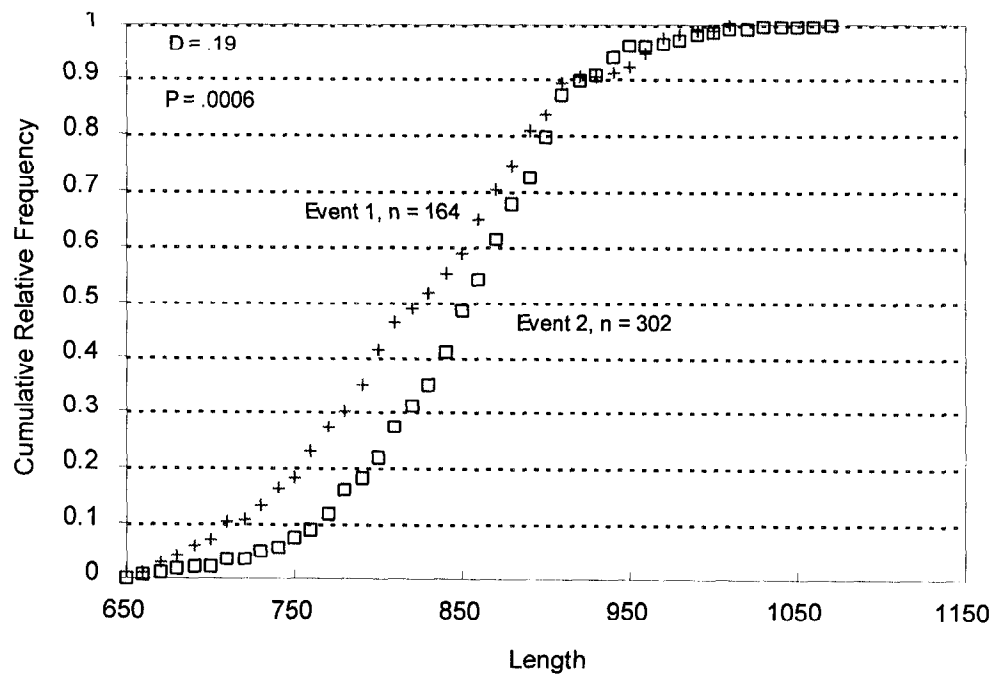
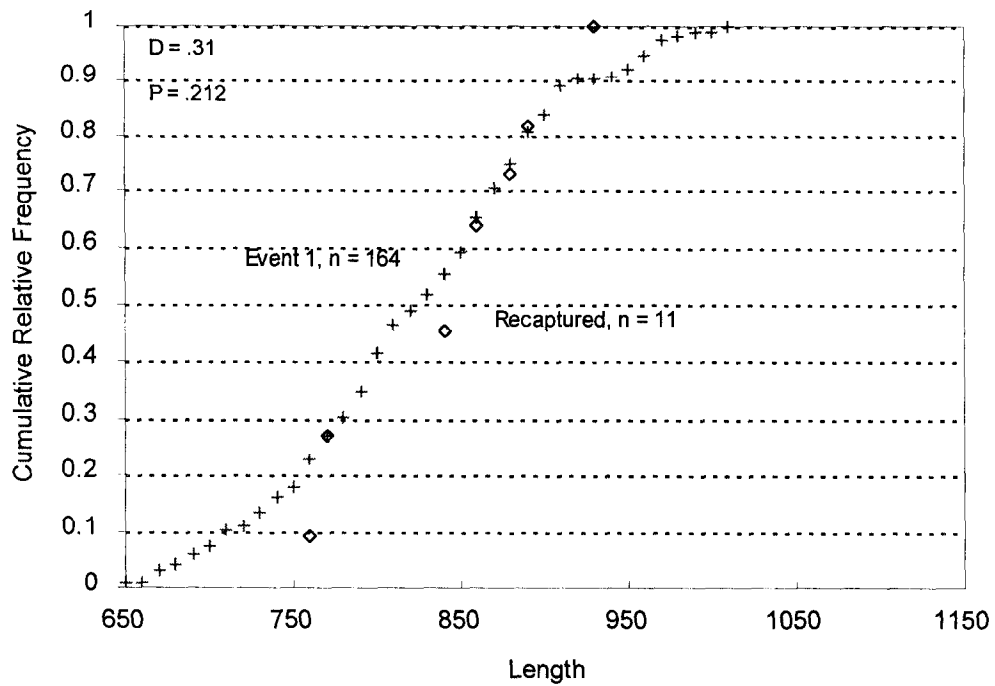


Figure 6.—Cumulative relative frequency of large chinook salmon captured in event 1 (lower river setnet) and marked chinook salmon recovered in event 2 (spawning ground sampling) and cumulative relative frequency of chinook salmon captured in event 1 and all chinook salmon sampled in event 2.

Table 10.—Age composition of chinook salmon in the Unuk River mainstem and Johnson Slough (combined) set gillnet catch, by sex, age class, and fishing period, 1994.

Brood year and age class							
	1991	1990		1989		1988	1987
	1.1	0.3	1.2	0.4	1.3	1.4	1.5
Total							
PERIOD 1: SAMPLES TAKEN FROM JUNE 11 THROUGH JULY 1							
Male							
Sample size			1		8	17	26
Percent			1.7		13.6	28.8	44.1
SE			1.7		4.5	5.9	6.5
Female							
Sample size		1			9	23	33
Percent		1.7			15.3	39.0	55.9
SE		1.7			4.7	6.4	6.5
All fish							
Sample size		1	1		17	40	59
Percent		1.7	1.7		28.8	67.8	100.0
SE		1.7	1.7		5.9	6.1	
PERIOD 2: SAMPLES TAKEN JULY 2-25							
Male							
Sample size	2		6	1	24	11	45
Percent	2.4		7.1	1.2	28.6	13.1	53.6
SE	1.7		2.8	1.2	4.9	3.7	5.5
Female							
Sample size					13	26	39
Percent					15.5	31.0	46.4
SE					4.0	5.1	5.5
All fish							
Sample size	2		6	1	37	37	84
Percent	2.4		7.1	1.2	44.0	44.0	100.0
SE	1.7		2.8	1.2	5.4	5.4	1.2
COMBINED PERIODS							
Male							
Sample size	2		7	1	32	28	71
Percent	1.4		4.9	0.7	22.4	19.6	49.7
SE	1.0		1.8	0.7	3.4	3.3	4.2
Female							
Sample size		1			22	49	72
Percent		0.7			15.4	34.3	50.3
SE		0.7			3.0	4.0	4.2
All fish							
Sample size	2	1	7	1	54	77	143
Percent	1.4	0.7	4.9	0.7	37.8	53.8	100.0
SE	1.0	0.7	1.8	0.7	4.0	4.1	0.7

Table 11.—Estimated length composition of chinook salmon in the Unuk Mainstem and Johnson Slough (combined) set gillnet catch, by sex, age class, and fishing period, 1994.

		Brood year and age class						Total
		1991	1990		1989		1988	1987
		1.1	0.3	1.2	0.4	1.3	1.4	1.5
PERIOD 1: SAMPLES TAKEN FROM JUNE 11 THROUGH JULY 1								
Male								
	Avg. length			665		747	878	829
	SE					18.7	18.1	18.8
	Sample size			1		8	17	26
Female								
	Avg. length		810			804	860	843
	SE					14.7	11.0	9.6
	Sample size		1			9	23	33
All fish								
	Avg. length		810	665		777	868	837
	SE					13.4	9.9	9.8
	Sample size		1	1		17	40	59
PERIOD 2: SAMPLES TAKEN JULY 2-25								
Male								
	Avg. length	460		667	900	763	871	773
	SE			11.1		12.2	15.9	14.6
	Sample size	1		6	1	24	11	44
Female								
	Avg. length					758	859	825
	SE					14.1	11.0	11.6
	Sample size					13	26	39
All fish								
	Avg. length	460		667	900	761	862	797
	SE			11.1		9.2	9.0	9.8
	Sample size	1		6	1	37	37	83
COMBINED PERIODS								
Male								
	Avg. length	460		666	900	755	874	801
	SE		9.4	10.2	12.4		11.9	
	Sample size	1		7	1	32	28	70
Female								
	Avg. length		810			781	859	834
	SE					11.2	7.7	7.7
	Sample size		1			22	49	72
All fish								
	Avg. length	460	810	666	900	769	865	817
	SE			9.4		7.6	6.7	7.2
	Sample size	1	1	7	1	54	77	142

Table 12.—Estimated age composition of chinook salmon from spawning ground samples taken in the Unuk River (seven tributaries combined) by sex and age class from Aug. 6 through Sept. 2, 1994.

		Brood year and age class							Total
		1991	1990	1989	1988		1987		
		1.1	1.2	1.3	1.4	2.3	1.5	2.4	
Male									
Sample size		16	24	31	31		3		105
Percent		5.3	7.9	10.3	10.3		1.0		34.8
SE		1.3	1.5	1.7	1.7		0.6		2.7
Female									
Sample size				46	142	1	6	2	197
Percent				15.2	47.0	0.3	2.0	0.7	65.2
SE				2.0	2.8	0.3	0.8	0.5	2.7

Table 13.—Estimated length composition of chinook salmon from spawning ground samples taken in the Unuk River (seven tributaries combined) by sex and age class from Aug. 6 through Sept. 2, 1994.

		Brood year and age class						Total	
		1991	1990	1989	1988		1987		
		1.1	1.2	1.3	1.4	2.3	1.5		2.4
Male									
	Avg. length	395	604	761	891		945		713
	SE	12.0	14.5	7.5	12.4		58.0		18.0
	Sample size	16	24	30	31		3		104
Female									
	Avg. length			792	862	760	904	793	846
	SE			7.4	3.3		16.6	57.5	3.8
	Sample size			43	134	1	6	2	186

Table 14.—Estimated age composition of the inriver run of chinook salmon in the Unuk River by sex and age class, 1994.

		Brood year and age class									Total
		1991	1990		1989		1988		1987		
		1.1	0.3	1.2	0.4	1.3	1.4	2.3	1.5	2.4	
Male											
	Sample size	16		24	1	63	59		4		167
	Percent	15.2		22.9	0.5	30.7	28.8		1.9		58.2
	SE of %	4.4		5.7	0.5	4.4	4.2		1.0		4.6
	Escapement	527		790	17	1,061	994		67		3,455
	SE of esc.	207		291	18	320	302		39		616
Female											
	Sample size		1			68	191	1	6	2	269
	Percent		0.4			25.3	71.0	0.4	2.2	0.7	41.8
	SE of %		0.4			2.7	2.8	0.4	0.9	0.5	4.6
	Escapement		9			628	1,764	9	55	18	2,484
	SE of esc.		10			190	507	10	27	14	707
All fish											
	Sample size	16	1	24	1	131	250	1	10	2	436
	Percent	8.9	0.3	13.3	0.2	28.4	46.4	0.2	2.1	0.3	100.0
	SE of %	2.1	0.2	2.7	0.3	2.3	3.4	0.2	0.7	0.2	
	Escapement	527	9	790	17	1,689	2,757	9	123	18	5,939
	SE of esc.	207	10	291	18	373	590	10	47	14	1,346

One adipose finclipped chinook salmon was recovered from the spawning grounds in 1994. The CWT indicated the fish was from a group of Unuk River broodstock fish from Deer Mountain Hatchery released in 1991 near Bell Island, in northwest Behm Canal.

CONTRIBUTIONS TO FISHERIES FROM THE 1992 AND 1993 BROOD YEARS

During October 1993, 13,959 juveniles from the 1992 brood year were tagged with CWTs, and another 2,642 smolt from the 1992 brood were tagged in May of 1994. In October, 1994 20,542 fish from the 1993 brood year were tagged. These fish will return from 1995 through 2000.

DISCUSSION

Concerns about a possible conservation problem for Behm Canal chinook stocks are almost entirely the result of the decline in observed escapement counts from 1988 to 1993. Similar concerns over low observed escapement counts in the Chilkat River had resulted in fishery restrictions and an adult mark-recapture and radio tagging study in 1991 and 1992 (Johnson et al. 1992). The Chilkat River studies showed the spawning distribution to be greatly different from the surveyed index areas and the mark-recapture estimate was an order of magnitude higher than the observed counts. In that case, the index areas proved to not be representative of the actual escapement and the surveys were discontinued. The Chilkat study cast some doubt on other chinook index surveys that haven't been validated by weir counts or mark-recapture studies.

This study does not address the conservation issue directly, but shows that escapement to the Unuk River in 1994 was 4.1 times greater than previously assumed expansion factors would have indicated (see Table 1 and Pahlke 1995; Unuk River index counts are normally expanded by 1.6 to estimate escapement). Notably, aerial surveys of the Unuk River in 1994 yielded relatively low counts, we think, due to poor survey conditions (high water levels) at Cripple Creek and Genes Lake Creek, the two most important spawning areas.

Also, the distribution of radio tagged fish in 1994 show that index *streams* (Table 1) surveyed since 1976 received: (a) the majority (80.4%) of the escapement in 1994 (Table 4), and (b) escapements in proportions roughly similar to those obtained in average historical index surveys (Table 15).

Most of the fish tracked into Canada (Appendix B) were not tracked to a spawning tributary, and most of them were only located once because of the time and expense involved in surveying in Canada. There are almost no clear water tributaries above the US/Canada border. It is possible some of these fish spawned in the glacial water (as a few appeared to do in the U.S.) or moved downstream to known (U.S. or Canadian) spawning areas after the last radio-tracking survey.

About 15.4% (or 711) of the estimated 4,623 large chinook salmon immigrating to the Unuk River in 1994 were counted in the peak aerial survey. Much lower percentages were observed in the Chilkat River, a glacial Southeast Alaska chinook salmon system where few clearwater tributary areas are available to count spawning fish (Johnson et al. 1992, 1993). In contrast, Skaugstad (1993) found that aerial surveys for chinook salmon accounted for between 19% and 71% of the mark-recapture estimate on the Salcha River, a large clearwater tributary of the Yukon, depending on the size of the escapement and survey conditions.

A concern in planning this study was that fish bound for varied spawning sites might be heterogeneously distributed across entry channels in the lower Unuk River and fish bound for some areas (e.g., Eulachon River) might therefore be disproportionately sampled. Sampling sites were located on both of the main channels (Figure 3), although the Eulachon River lay below both sites. Fish bound for the Eulachon River migrated several miles beyond the mouth of the Eulachon in 1994 and were captured at both gillnet sites (Table 4). Ten percent (10%) of the fish successfully radio-tracked from the Johnson Slough site were destined for the Eulachon River, and 6% of the fish tracked from the mainstem

site were so bound. Although sample sizes are small (Table 5), tag recovery rates on the Eulachon River (0.048) and other spawning areas (0.031) were not significantly different ($\chi^2 = 0.18$, $P = 0.67$). Also, we did not find a statistical difference in upriver or downriver spawning distributions of fish marked at each site (Table 7).

In a related matter, we observed harbor seals pursuing salmon near both gillnet sites and the Eulachon River, and bears feed heavily on spawning fish throughout the drainage. In these circumstances, remaining in deep mainstem glacial waters prior to spawning may be an effective survival trait. Similarly, we saw “bright” fish with sea lice (indicating recent entry into fresh water) (McLean et al. 1990) in our gillnets as late as July 25, and “dark” fish without lice were caught as early as June 17. Fish tagged with radio transmitters often remain in the lower reaches of a river (near a tagging site) for several weeks prior to migrating to spawning sites, and some fish retreat to salt water for a period after tagging (Eiler 1990). For example, one fish tagged in this study on June 26 in Johnson Slough (fish No. 5, Appendix B) was next located on July 20 at the mouth of the river, after which it proceeded quickly to Cripple Creek (17 miles in 8 days). Once fish with transmitters started moving upriver, they traveled about one mile/day.

Several assumptions required to estimate the distribution and abundance of spawning chinook salmon in this study deserve additional discussion. Our primary strategy for satisfying assumptions of both the distribution and abundance studies was to maintain constant fishing effort across the migration. Fishing effort was not, however, held completely constant (largely at Johnson Slough) during the peak of the immigration (Figure 4). However, because tests to detect different tagging fractions and/or migratory timing of up- and downriver stocks were negative, we cannot conclude a problem resulted from the variations in tagging effort over time.

Another assumption was that tagging did not affect fish behavior. A direct test of this assumption was not made. However, the high

percentage of fish successfully tracked to spawning areas (86%) and the similarity of the average historical and estimated 1994 distribution (Table 15) indicate this assumption was reasonable. Also, we assumed fates of fish carrying radio transmitters were accurately determined. While we again have no direct test of this assumption, only seven (of 101 live/mobile) fish with ambiguous tracking records (“unknown” fates) occurred. Therefore, potential biases in the estimated proportions would most likely be small, unless several of these seven fish were bound for a minor spawning area (e.g., mainstem spawning). Another concern is that transmitter motion and mortality signals can lead to ambiguous, inconsistent conclusions about the fate of a tracked fish (Bendock and Alexandersdottir 1992; Johnson et al. 1992; John Eiler, NMFS Auke Bay Laboratory, personal communication). Again, this difficulty should lead to significant bias only under the unlikely condition noted above.

Two other difficulties in the study are hard to resolve. First, statistical tests to detect departures from assumptions of experiments (Tables 6–9) have low power to identify departures from desired conditions. We had neither the ability to boost sample sizes greatly (to remove this problem), nor have we undertaken simulation studies to discern the extent to which biases might exist in worst-case situations. However, we take some comfort from a belief the experimental design is otherwise sound and that significant departures from the assumptions have not been identified in similar, previous studies (Johnson et al. 1992, 1993). One relatively simple method of addressing this problem in future studies is to increase sample sizes in spawning ground surveys. However, sampling can be hindered (as it was in 1994) by continued high water in the important spawning areas.

Second, it was apparent from length and sex composition data in this study that size selective sampling occurred in the spawning surveys and during gillnet fishing. Gillnets are well documented to be size selective, but for the fish of interest in this experiment (length ≥ 660 mm MEF), gillnets do not show strong selectivity. In addition, the age composition of the large fish

Table 15.—Distribution of large spawning chinook salmon in the Unuk River drainage from 1994 radio-tracking and historical surveys, with and without a correction for unsurveyed spawning areas.

Spawning area	Radio tracking	Aerial surveys			
	1994	1994 ^a		78-94 Avg.	
Eulachon River	8.7	7.0	(5.6)	18.5	(14.9)
Clear and Lake creeks	13.1	21.0	(16.9)	10.4	(8.4)
Kerr Creek	3.6	7.0	(5.6)	2.4	(1.9)
Genes Lake Creek	18.8	42.0	(33.8)	28.6	(23.0)
Cripple Creek	36.2	23.0	(18.5)	40.1	(32.2)
Border Creek	3.6	NS		NS	
Canada (unsurveyed)	13.8	NS		NS	
Mainstem Unuk (USA)	2.2	NS		NS	
	100	100.0	(80.4)	100	(80.4)

^a In parentheses are proportions discounted by 0.804, the estimated proportion of radio-tagged fish that spawned in index areas in 1994.

NS = not surveyed for index.

captured in the gillnets was similar to that of the spawning ground escapement sample (Tables 10 and 12).

Spearing dead and dying fish was our primary method of collecting fish on the spawning grounds. There are two possible problems with this method of sampling. First, behavior differences between sexes (commitments to redds after spawning) may result in selective sampling, as noted earlier. Also, females tend to develop white tails which are quite visible as they remain near their redds, while males do not. This further causes selective sampling of females, because they are relatively easier seen. There are other methods which might be used to obtain large, unbiased samples on the spawning grounds in these conditions. One method is to build upstream migrant weirs. Also, dip nets, seines, and angling could be used to sample pre-spawning fish in a more random manner. A large unbiased sample of the escapement is also needed to estimate the fraction of the population marked with CWTs, which in turn is necessary to estimate the harvest of the population.

CONCLUSIONS AND RECOMMENDATIONS

Operation of set gillnets was an effective method of capturing large chinook salmon migrating up the Unuk River. Handling mortality was low and catches were sufficient to successfully complete the distribution study. With 92 radio tags successfully tracked to spawning areas, the objective of determining the location of all the major spawning areas in the Unuk River was met. Distribution of radio tags in 1994 was similar to the average index survey distribution. Therefore, index area counts were representative of the actual escapement distribution, but underestimate the magnitude of the escapement. The project should be repeated to provide replicates of the 1994 study, with modifications in event 2 required to increase the sample size and account for size selectivity.

ACKNOWLEDGMENTS

Dave Magnus, Dave Dreyer, Red Weller, Dale Brandenburger, Jim Foster, Grant Ness, and Peter Montesano conducted field work and data collection. Amy Holm was the logistics coordinator in Ketchikan. Vern Beier, Dennis Hubartt, Jerry Koerner, Steve Elliott, Andy Piston, Kent Crabtree, Mark Olsen, Brian Glynn, Alma Seward and others helped with many aspects of the project. John Eiler of the NMFS Auke Bay Lab loaned us the telemetry equipment and shared his expertise. Don House, Heather Swearington, and Mary Urquhart assisted frequently in relaying radio messages and responded immediately when a serious accident occurred in the field. Many of the residents of the Unuk River, especially Charlie Pinkerpank and Don Ross provided assistance to the field crew. Staff of the Misty Fiords National Monument was helpful in the operation of the project.

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**APPENDIX A. CHINOOK SALMON TAGGING RECORDS,
UNUK RIVER, 1994**

Appendix A1.—Fish number, tagging date and time, transmitter frequency and/or spaghetti tag number, sex, length, age and fate of fish marked on the Unuk River mainstem site, 1994.

Fish no.	Coun no.	Tag date	Time	Sheet freq.	Adjust freq.	Spag. tag	Sex	Lic	Length	Age	Fate/destination
102	1	6/11	14:25	31.592	31.592	916	m	n	900	1.3	Cripple Cr.
103	2	6/13	14:25	31.632	31.632	894	f	n	880	1.4	Cripple Cr.
104	3	6/13	16:25	31.652	31.652	896	f	p	998	1.4	Unknown
106	4	6/14	13:20	31.662	31.660	898	m	p	745	r3	Canada
107	5	6/15	10:35	31.692	31.690	900	f	n	880	1.4	Mort/Regurg
109	6	6/15	11:15	31.712	31.710	889	m	n	930	1.3	Mainstem
108	7	6/15	10:50	31.722	31.720	885	f	n	790	1.4	Canada
110	8	6/15	17:25	31.732	31.731	890	m	n	950	1.4	Genes Lake
112	9	6/16	11:25	31.742	31.742	893	f	p	790	1.3	Unknown
113	10	6/16	14:00	31.672	31.670	827	m	n	900	1.4	Cripple Cr.
114	11	6/16	16:10	31.680	31.678	882	f	n	785	1.3	Unknown
115	12	6/16	16:45	31.702	31.701	891	m	p	880	1.4	Cripple Cr.
116	13	6/16	17:50	31.752	31.752	881	f	p	940	1.4	Cripple Cr.
118	14	6/17	13:25	31.762	31.760	897	m	n	1000	1.4	Canada
119	15	6/17	13:35	31.772	31.771	886	m	p	790	1.3	Mort/Regurg
120	16	6/17	15:25	31.782	31.779	892	f	p	750	1.3	Canada
121	17	6/18	10:15	31.792	31.789	882	f	p	895	1.4	Cripple Cr.
122	18	6/18	11:07	31.802	31.799	876	f	p	860	r4	Genes Lake
123	19	6/18	11:17	31.811	31.809	877	f	p	775	r4	Clear/Lake
124	20	6/18	12:45	31.822	31.819	878	m	p	895	1.4	Mort/Regurg
125	21	6/18	14:35	31.830	31.828	879	m	n	765	r4	Eulachon
126	22	6/19	12:10	31.840	31.838	875	f	p	890	1.3	Mort/Regurg
127	23	6/20	12:30	31.852	31.850	874	f	p	840	r4	Cripple Cr.
128	24	6/20	15:25	31.862	31.859	899	f	p	790	1.3	Canada
129	25	6/22	09:25	31.872	31.870	880	m	p	820	1.3	Cripple Cr.
130	26	6/22	13:25	31.890	31.890	895	m	n	725	r3	Cripple Cr.
131	27	6/23	10:00	31.902	31.901	818	m	p	845	1.4	Canada
132	28	6/23	13:48	31.910	31.909	868	f	n	810	1.4	Mort/Regurg
133	29	6/28	11:50	31.922	31.920	871	f	p	830	1.4	Mort/Regurg
134	30	6/28	13:20	31.930	31.927	870	m	p	725	1.3	Cripple Cr.
135	31	6/29	11:20	31.942	31.940	869	f	p	795	1.3	Genes Lake
136	32	6/29	16:00	31.952	31.951	866	m	n	940	r4	Genes Lake
137	33	6/29	16:10	31.962	31.961	863	f	p	740	1.4	Clear/Lake
138	34	6/30	10:00	31.972	31.969	872	m	p	865	1.4	Unknown
139	35	6/30	11:25	31.982	31.978	864	f	p	895	r4	Cripple Cr.
140	36	6/30	11:30	31.990	31.987	865	f	p	885	1.4	Genes Lake
141	37	6/30	12:50	31.202	31.199	860	m	n	860	1.4	Eulachon
142	38	6/30	13:30	31.233	31.229	861	f	p	865	1.4	Kerr Creek
143	39	6/30	14:00	31.242	31.238	862	m	p	750	1.3	Canada
144	40	6/30	14:20	31.252	31.248	859	f	p	845	1.4	Border Creek
145	42	6/30	15:50	31.262	31.259	855	f	p	820	1.4	Kerr
146	41	7/01	09:28	31.293	31.290	857	m	p	755	1.3	Canada
147	43	7/01	10:10	31.312	31.310	858	f	p	850	1.4	Cripple Cr.
148	44	7/01	11:10	31.322	31.320	852	m	p	745	1.4	Genes Lake
149	45	7/01	11:54	31.332	31.330	853	m	p	945	r4	Cripple Cr.
150	46	7/01	12:45	31.342	31.340	854	m	p	675	1.3	Genes Lake
151	47	7/01	15:00	31.352	31.350	856	f	p	760	1.4	Clear/Lake
152	48	7/01	15:15	31.362	31.360	846	m	p	745	1.4	Genes Lake
153		7/02	10:05			470	f	p	860	1.4	
154		7/02	10:20			467	f	p	810	0.3	
155	49	7/02	11:35	31.382	31.379	842	m	p	960	1.4	Border Creek
156	50	7/02	14:05	31.392	31.390	843	m	p	760	1.4	Unknown
157		7/02	16:10			468	f	p	875	1.4	
158	51	7/02	16:45	31.402	31.399	844	f	p	885	1.4	Canada

-continued-

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Fish no.	Count no.	Tag date	Time	Sheet freq.	Adjust freq.	Spag. tag	Sex	Lice	Length	Age	Fate/destination
159		7/03	10:20			469	m	p	975	1.4	
160	52	7/03	13:05	31.412	31.409	829	m	p	815	1.4	Cripple Cr.
161		7/03	13:41			474	m	n	820	1.3	
162	53	7/03	14:10	31.432	31.428	830	f	p	880	1.4	Clear/Lake
163		7/04	13:35			486	m	p	765	1.3	
164	54	7/04	14:10	31.442	31.440	834	f	n	845	1.4	Clear/Lake
165		7/05	10:10			471	m	p	825	1.4	
166	55	7/05	10:40	31.452	31.449	831	m	p	910	1.4	Cripple Cr.
167		7/05	12:45			485	f	n	900	1.4	
168	56	7/05	13:05	31.462	31.459	850	f	n	850	1.4	Border Creek
169		7/05	14:45			473	m	p	660	1.3	
170	57	7/05	15:05	31.472	31.469	847	m	n	725	r3	Canada
171		7/05	15:20			487	f	n	890	1.4	
172	58	7/05	15:45	31.482	31.478	851	f	p	870	1.4	Cripple Cr.
173		7/05	16:35			484	m	p	705	1.3	
174	59	7/05	16:45	31.502	31.499	841	f	p	695	1.3	Cripple Cr.
175	60	7/06	09:25	31.512	31.511	845	f	p	775	r3	Unknown
176		7/06	10:30			491	f	p	870	1.4	
177		7/06	10:55			472	f	p	815	r4	
178	61	7/06	11:10	31.522	31.519	838	m	p	700	1.3	Canada
179		7/06	13:42			492	f	n	840	1.4	
180	62	7/08	14:18	31.530	31.532	832	m	p	860	1.4	Clear/Lake
181		7/09	16:45			494	f	n	685	1.3	
182	63	7/10	16:15	31.540	31.537	849	m	p	805	1.3	Unknown
183		7/11	09:50			476	f	p	885	1.4	
184	64	7/11	11:15	31.552	31.550	833	f	n	905	1.4	Canada
185		7/11	14:30			477	f	n	840	1.4	
186	65	7/12	09:30	31.560		839	f	p	880	1.4	Mort/Regurg
187		7/12	09:40			478	m	p	880	1.3	
188	66	7/12	15:00	31.572		836	f	n	740	1.3	Genes Lake
189		7/12	15:40			479	f	n	775	1.4	
190	67	7/13	11:15	30.010		848	f	p	800	-	Cripple Cr.
191		7/13	12:00			475	f	p	850	1.4	
192	68	7/13	13:25	30.020		837	m	p	955	1.4	Genes Lake
193		7/13	13:50			481	f	p	805	1.4	
194	69	7/13	14:45	30.030		840	f	n	790	1.3	Kerr
195		7/13	15:45			480	f	p	830	r3	
196		7/13	16:00			495	m	n	785	1.3	
197	70	7/14	10:30	30.040		835	f	p	695	1.3	Genes Lake
198	71	7/15	13:20	30.050		746	m	p	700	1.2	Cripple Cr.
199		7/16	10:10			489	f	p	780	1.4	
200	72	7/16	11:20	30.060	30.057	749	m	p	660	1.2	Eulachon
201		7/17	14:40			482	f	p	830	1.4	
202	73	7/18	15:15	30.070	30.067	751	f	p	720	1.4	Cripple Cr.
203		7/19	13:15			483	f	p	795	1.4	
204	74	7/21	11:50	30.080	30.078	750	m	p	800	1.3	Cripple Cr.
205		7/21	13:40			490	m	p	950	r4	
206	75	7/21	13:50	30.090	30.088	748	m	n	855	1.4	Clear/Lake
207		7/21	14:30			488	f	n	785	1.3	
208	76	7/22	10:20	30.100	30.098	747	f	p	795	1.3	Cripple Cr.
209		7/22	14:00			493	f	n	850	1.4	
210	77	7/24	10:30	30.110	30.110	750	f	p	785	r3	Cripple Cr.
211		7/24	11:20			752	m	p	760	1.3	
212	78	7/24	11:56	30.120	30.120	756	m	p	840	1.4	Eulachon
213		7/24	13:08			753	f	p	965	1.4	
214	79	7/24	15:15	30.130	30.129	759	m	p	725	1.3	Clear/Lake
215		7/25	15:10			754	m	n	680	1.3	

Lice: p = sea lice present, n = sea lice not present.

Age = r.*, freshwater age regenerated, marine age still determined.

Appendix A2.—Fish number, tagging date and time, transmitter frequency and/or spaghetti tag number, sex, length, age and fate of fish marked on the Unuk River, Johnson Slough site, 1994.

Fish no.	Count no.	Tag date	Time	Sheet freq.	Adjust freq.	Spag. tag	Sex	Lice	Length	Age	Fate/destination
101	1	6/11	13:40	31.610	31.609	916	m	n	900	1.4	Cripple Cr.
105	2	6/13	14:10	31.620	31.621	920	m	n	855	1.4	Cripple Cr.
111	3	6/15	14:25	31.642	31.643	918	m	p	665	1.2	Canada
117	4	6/17	14:43	31.002	31.002	926	m	n	785	1.3	Genes Lake
1	5	6/18	09:15	31.012	31.012	927	f	p	715	r3	Cripple Cr.
2	6	6/19	15:25	31.022	31.022	928	m	p	875	1.4	Kerr
3	7	6/25	11:37	31.033	31.033	929	f	p	865	1.4	Genes Lake
4	8	6/26	08:30	31.042	31.042	932	f	n	860	1.4	Cripple Cr.
5	9	6/26	09:05	31.053	31.052	930	m	n	685	r3	Cripple Cr.
6	10	6/28	10:20	31.062	31.062	931	f	n	830	r4	Clear/Lake
7	11	6/28	11:45	31.093	31.093	999	f	n	845	1.4	Cripple Cr.
8		7/01	09:50			1000	m	p	675	1.3	
9	12	7/01	12:10	31.102	31.103	998	f	n	865	1.4	Cripple Cr.
10		7/02	13:05			3128	m	p	960	1.4	
11	13	7/02	13:30	31.112	31.112	997	f	n	780	1.3	Genes Lake
12		7/05	13:30			3129	m	p	800	1.3	
13	14	7/06	08:50	31.122	31.122	994	m	p	840	1.3	Canada
14		7/11	10:30			3133	f	n	770	r3	
15	15	7/11	13:00	31.133	31.133	995	f	n	795	1.3	Cripple Cr.
16		7/11	14:35			3131	m	n	840	1.4	
17	16	7/12	10:10	31.143	31.143	996	f	p	875	1.4	Mainstem
18		7/12	10:50			3134	f	n	945	1.4	
19	17	7/12	10:50	31.153	31.153	985	m	p	775	r3	Genes Lake
20		7/12	11:10			3135	m	n	720	1.3	
21	18	7/12	11:45	31.162	31.162	993	m	n	720	1.3	Cripple Cr.
22		7/12	13:10			3130	m	p	745	1.3	
23	19	7/12	13:20	31.172	31.172	986	f	p	730	1.3	Clear/Lake
24		7/12	14:08			5101	m	n	755	1.3	
25		7/12	14:18			5107	f	p	855	r4	
26	20	7/12	14:35	31.192	31.192	987	m	p	765	1.3	Genes Lake
27		7/12	14:45			3132	f	n	850	1.3	
28		7/12	14:55			5098	m	p	750	1.3	
29		7/12	15:00			5106	m	p	780	1.3	
30		7/12	16:30			119	m	p	845	1.4	
31	21	7/13	11:20	30.210	30.210	982	m	n	670	1.2	Mort/Regurg
32	22	7/13	12:10	30.220	30.220	980	f	p	760	r3	Cripple Cr.
33	23	7/13	12:30	30.230	30.230	981	f	p	800	1.3	Cripple Cr.
34										1.1	jack
35	24	7/14	09:00	30.240	30.240	977	f	p	900	1.4	Eulachon
36	25	7/14	13:35	30.250	30.250	979	f	n	640	1.2	Genes Lake
37		7/14	14:23			122	m	p	830	1.4	
38	26	7/16	09:00	30.260		978	m	n	900	0.4	Eulachon
39		7/18	12:12			123	m	p	655	1.3	
40	27	7/18	15:17	30.190	30.190	984	m	n	760	1.3	Genes Lake
41		7/22	13:00			118	m	p	695	1.2	
42	28	7/22	15:20	30.200	30.200	972	m	p	860	1.4	Cripple Cr.
43		7/24	12:25			117	m	p	740	1.5	
44	29	7/25	08:20	30.270	30.271	975	f	n	775	1.3	Clear/Lake
45		7/25	09:40			124	m	n	750	r4	
46	30	7/25	13:45	30.280	30.280	973	f	p	715	1.3	Eulachon
47		7/28	13:55			121	f	n	960	r5	

**APPENDIX B. LOCATION OF RADIO TRANSMITTERS
INSERTED IN LARGE CHINOOK SALMON, UNUK RIVER, 1994**

Appendix B1.—Location of radio transmitters inserted in large chinook salmon at the mainstem site on the Unuk River in 1994, by frequency, date tagged, tributary/river mile where located, and survey type and date.

fish no.	ct no.	tag date	sheet freq.	A 6/20	A+B 6/24	A+B 6/29	B 7/3	A-7/8 B-7/9	A 7/11	H 7/13	B-7/19 A-7/20	B-7/27 A-7/28	B-8/3 H-8/5	B-8/9 H-8/12	A-8/18	H-8/29	Fate/ Destination
102	1	6/11	31.592		(B)M2					(H)M2-M	M18-M	M17-M	(B)M17-M	CR1M	X	X	Cripple Cr.
103	2	6/13	31.632	M10	(B)M11	(B)M10	(B)M10	(A)M15	(A)CR1		M21	M17		CR1M	X	X	Cripple Cr.
104	3	6/13	31.652													X	Unknown
106	4	6/14	31.662		(B)M9	(A)M17		(A)M23	(A)CM26	(H)CM26	CM27			M22		X	Canada
107	5	6/15	31.692	JS2.5	(B)M2	(B)M3	(B)M3-M	(B)M3	(A)M3-M		M2-M?	(B)M4-M	(B)M4	M4		X	Mort/Regurg
109	6	6/15	31.712	M3.5	(B)M12	(A)M15		(A)M15			(B)M12					X	Mainstem
108	7	6/15	31.722		(B)M2	(A)M17	(B)M5-M		(A)M22		M22			CM31M		X	Canada
110	8	6/15	31.732	M7	(B)M2		(B)M3	(A)M3	(A)M11		(B)G1	(B)G1	(B)G1	G1	X	X	Genes Lake
112	9	6/16	31.742		(B)M2											X	Unknown
113	10	6/16	31.672					(B)M9-KS	M15		(B)CR1		(B)CR1	CR1	X	X	Cripple Cr.
114	11	6/16	31.680							M11							Unknown
115	12	6/16	31.702	M9	(B)M12	(B)M15	(B)M15	(A)M18			M18	M17/18	CR2-M	CR2M	X	X	Cripple Cr.
116	13	6/16	31.752		(B)M13	(A)M15		(A)M15	(A)M15		(B)M17		CR2-M	CR2M	X	X	Cripple Cr.
118	14	6/17	31.762								(B)M13		CM24				Canada
119	15	6/17	31.772	M3	(A)M3	(B)M3-M	(B)M3-M	(B)M3-M			(B)M3-M	(B)M3-M	(B)M3-M	M3M	X	X	Mort/Regurg
120	16	6/17	31.782		(B)M12	(B)M13	(B)M15	(A)M15	(A)M19		CM27			M17		X	Canada
121	17	6/18	31.792	M7	(B)M6	(B)M12		(A)M12	(A)M14		(B)CR1	CR1-M	CR1-M	CR1-M	X	X	Cripple Cr.
122	18	6/18	31.802		(B)M2-M	(B)M2-M	(B)M10-	(A)M12-			G1		G4-M	G4M	X	X	Genes Lake
123	19	6/18	31.811			(B)M4				(H)L1		(B)M6-M	(B)M6-M	M6M	M6M	X	Clear/Lake
124	20	6/18	31.822	M5	(B)M5-M	(B)M5-M	(B)M5-M	(A)M5			(B)M5-M	(B)M5-M	(B)M5-M	M5M	X	X	Mort/Regurg
125	21	6/18	31.830	M5		(B)M5-M	(B)M4-M						H3	H4	H3	X	Eulachon
126	22	6/19	31.840	M7	(B)M10	(B)M10	(B)M--M	(B)M12-M	(A)M12-		(B)M12-	(B)M12-	(B)M12-M	M12M	X	X	Mort/Regurg
127	23	6/20	31.852		(B)M10	(B)M5		(A)M13			(B)CR1	CR1	CR2	CR1	X	X	Cripple Cr.
128	24	6/20	31.862		(B)M12	(B)M13		(A)M22			CM30			M24M		X	Canada
129	25	6/22	31.872		(B)M6	(B)M8		(A)M13	(A)M15		(B)M17	M17	CR1	CR1	X	X	Cripple Cr.
130	26	6/22	31.890		(B)M2	(B)M6		(B)M10	(A)M11		(B)M17	M17	(B)CR1	CR1	X	X	Cripple Cr.
131	27	6/23	31.902		(B)M2	(B)M9	(B)M4	(A)M12	(A)M16		M12	M12	BH-CM24	CM26		X	Canada
132	28	6/23	31.910		(A)M2	(B)M2	(B)M2	(B)M2-M	(A)M2-M		(B)M2-M	(B)M2-M	(B)M2-M	M2M	X	X	Mort/Regurg
133	29	6/28	31.922			(B)M4		(B)M10-M	(A)M9		(B)M8-M	(B)M8-M	M9	M10M	M10M	X	Mort/Regurg
134	30	6/28	31.930					(A)M7	(A)M11		(B)M16-	M17	CR1	CR1	X	X	Cripple Cr.
135	31	6/29	31.942					(B)M10	(A)M12		(B)G1	(B)G1		G2	X	X	Genes Lake
136	32	6/29	31.952				(B)M7	(B)M9-KS	(A)M11		(B)M12	(B)M10	(B)G1	G2	G2	G1M	Genes Lake

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137	33	6/29	31.962					(H)L2	L2	(B)L1	(B)L2	L2	X	X	Clear/Lake
138	34	6/30	31.972											X	Unknown
139	35	6/30	31.982		(B)M10	(A)M12	(A)M18		(B)CR1-	CR1-M	(B)CR1-M	CR1M	X	X	Cripple Cr.
140	36	6/30	31.990		(B)M2	(B)M9-KS	(A)M9		(B)M12		(B)G2	G2	X	X	Genes Lake
141	37	6/30	31.202		(B)M2			(H)JS3			H4	H4M	H4M	X	Eulachon
142	38	6/30	31.233		(B)M8	(B)M9-KS			M11	(B)M10	K1	M10	K1M	X	Kerr Creek
143	39	6/30	31.242		(B)M10	(A)M19	(A)M18		M23			CM27M		X	Canada
144	40	6/30	31.252		(B)M15	(A)M17	(A)M18		M23	B-M23/B1		M12M	M12M	X	Border
145	42	6/30	31.262		(B)M6	(B)M10	(A)M12		(B)M9	(B)M10	(B)M10	M10M	K1M		Kerr
146	41	7/01	31.293		(B)M-	(B)G1	(A)M16		M22			SF3	SF2	X	Canada
147	43	7/01	31.312		(B)M-	(B)M13	(A)M13		M18		CR1-M	CR1M	X	X	Cripple Cr.
148	44	7/01	31.322		(B)M1	(B)G1	(A)M12		(B)M12	(B)G1	(B)G2	G2	X	X	Genes Lake
149	45	7/01	31.332		(B)M5	(A)M5	(A)M10		(B)M16	M17	(B)CR1	CR1M	X	X	Cripple Cr.
150	46	7/01	31.342		(B)M10	(B)M12	(A)M12		(B)G1	(B)G1	(B)G1	G1	X	X	Genes Lake
151	47	7/01	31.352		(B)M2	(B)M1	A)M4		(B)L1	(B)C1/L1	(B)M12			X	Clear/Lake
152	48	7/01	31.362		(B)M-	(A)M10	(A)M10		(B)M12	(B)G1	(B)G2	G2	X	X	Genes Lake
155	49	7/02	31.382				(A)M10		(B)CR1	M23	BH-	B1M	FOUND	X	Border
156	50	7/02	31.392		(B)M2	(B)M10	(A)M15							X	Unknown
158	51	7/02	31.402			(A)M4	(A)M10		(B)M12	CM27/28	(B)CM27	CM27		X	Canada
160	52	7/03	31.412			(B)M11	(A)M15		(B)G1	M16	CR2-M	CR2M	X	X	Cripple Cr.
162	53	7/03	31.432			(B)M6		(H)M9	(B)L1	(B)M7	(B)C1/L1	C1M	C1M	X	Clear/Lake
164	54	7/04	31.442				(A)M5	(H)M4	(B)L1	L1	(B)C1/L1	L1	M5M	X	Clear/Lake
166	55	7/05	31.452						(B)M13	M17	CR1-M	CR1M	X	X	Cripple Cr.
168	56	7/05	31.462			(B)M8			Mouth			M23M		X	Border
170	57	7/05	31.472						M12weird	M27/28		CM31		X	Canada
172	58	7/05	31.482			(A)M3			M9	M17	CR2	CR2M	X	X	Cripple Cr.
174	59	7/05	31.502			(A)M2	(A)M10		(B)M12	M22	(B)CR1	CR1	X	X	Cripple Cr.
175	60	7/06	31.512			(B)M3-M	(A)M10		(B)M12			M21M		X	Unknown
178	61	7/06	31.522			(A)M6	(A)M15		(B)M17			CM33		X	Canada
180	62	7/08	31.530						M6	(B)L1/M6		L1	L1M	X	Clear/Lake
182	63	7/10	31.540						M20					X	Unknown
184	64	7/11	31.552				(A)M2	(H)M11	M14			CM39		X	Canada
186	65	7/12	31.560						M1-M	(B)M1-M		BAY M	BAY M	X	Mort/Regurg
188	66	7/12	31.572						M9	(B)G1		M15		X	Genes Lake
190	67	7/13	30.010						M11	(B)M14	CR1	CR1M	X	X	Cripple Cr.
192	68	7/13	30.020						(B)M6	(B)G1	(B)G2		G2		Genes Lake

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194	69	7/13	30.030			M10	K1	K1	X	X	Kerr	
197	70	7/14	30.040		M6	(B)G1					G1M	Genes Lake
198	71	7/15	30.050		(B)M10	M17	(B)CR1	CR1M	X	X		Cripple Cr.
200	72	7/16	30.060			J1	H3	H3	H3M	X		Eulachon
202	73	7/18	30.070		M6	M21	CR1	M19M	M19M	X		Cripple Cr.
204	74	7/21	30.080			M17	(B)M18	CR1	CR1M	X		Cripple Cr.
206	75	7/21	30.090			(B)M6	(B)C1/L1	L3	L3	X		Clear/Lake
208	76	7/22	30.100			(B)M9-M	CR1	CR1		X		Cripple Cr.
210	77	7/24	30.110			(B)M10	(B)M17	CR1	CR1M	X		Cripple Cr.
212	78	7/24	30.120					H3	H4	H4	X	Eulachon
214	79	7/24	30.130				(B)M7	(B)C1/L1	L1	C1	X	Clear/Lake

Survey Type: A = fixed wing aerial, H = Helicopter, B = Boat.

Location: (A)B1-M, (A) = survey type, B1 = tributary and river mile, M = mortality signal, X = frequency was not looked for during that survey.

Tributary Codes: M = mainstem, J = Johnson Slough, H = Eulachon, K = Kerr, G = Genes Lake, C = Clear Lake, CR = Cripple Creek, B = Border Creek, CM = Canada Mainstem, SF = South Fork Can..

Appendix B2.—Location of radio transmitters inserted in large chinook salmon at the Johnson Slough site on the Unuk River in 1994, by frequency, date tagged, tributary/river mile where located, and survey type and date.

				1	2	3	4	5	6	7	8	9	10	11	12	13	
fish no.	cnt no.	tag date	sheet freq.	A 6/20	A+B 6/24	A+B 6/29	B 7/3	A-7/8 B-7/9 7/11	A 7/13	H 7/13	B-7/19 A-7/20	B-7/27 A-7/28	B-8/3 H-8/5	b-8/9 H-8/12	A-8/18	H-8/29	Fate/ Destination
101	1	6/11	j31.61 0		(B)M8	(B)M1 2			M17		M18	M18	(B)M18	CR2M	CR2 M	X	Cripple Cr.
105	2	6/13	j31.62 0	M8	M16	(B)M1 5				CR1	M18			CR1M		X	Cripple Cr.
111	3	6/15	j31.64 2	JS7		(B)M1 5		M21	CM 26		CM26			CM39 M	CM3 9M	X	Canada
117	4	6/17	31.002	JS2												G2	Genes Lake
1	5	6/18	31.012	JS6	(B)M1 0	(B)M1 2-M	(B)M 14	M12	M8		(B)CR 1			CR1	X	X	Cripple Cr.
2	6	6/19	31.022	M8	M12	M16		M12	M12		M13	(B)M1 1	K1	K1M	X	X	Kerr
3	7	6/25	31.033			(B)J1	(B)M 4	M12	M12		M12	(B)G1	(B)G2	G1	X	X	Genes Lake
4	8	6/26	31.042			(B)J1	(B)M 5	(B)M 8	M10		M16		(B)CR1	CR1M	X	X	Cripple Cr.
5	9	6/26	31.053								Mouth	M17	CR1-M	CRM	X	X	Cripple Cr.
6	10	6/28	31.062			(B)J1		(B)M 7	M6		CL1	(B)CL 1	(B)M4- M	M5M	M4M	X	Clear/Lake
7	11	6/28	31.093			(B) BAY			M13		M18/ CR1			CR1M	X	X	Cripple Cr.
9	12	7/1	31.102					(B)M 8	M11		M13	M17		CR1M	CR2 M	X	Cripple Cr.
11	13	7/2	31.112				(B)J1	(B)M 7	M8		G1	(B)G1	(B)G1	G1	X	X	Genes Lake
13	14	7/6	31.122						M10		M17	M20		CM32	CM3 2	X	Canada
15	15	7/11	31.133						J1	M11	M13		CR1	CR1	CR1 M	X	Cripple Cr.
17	16	7/12	31.143								M7	(B)M6	(B)M5- M	M5M	M5M	X	Mainstem
19	17	7/12	31.153								M8		(B)G1	G1	G2	G1	Genes Lake
21	18	7/12	31.162								M10	M17	(B)CR1	CR1		X	Cripple Cr.
23	19	7/12	31.172								M8	(B)M1 3		C1	C1	X	Clear/Lake
26	20	7/12	31.192											G1			Genes Lake
31	21	7/13	30.210										(B)M8	M8M		X	Mort/Regurg
32	22	7/13	30.220									(B)M9	(B)M17	CR1	CR2 M	X	Cripple Cr.
33	23	7/13	30.230								JS3	CR3	CR2	CR2	X	X	Cripple Cr.
35	24	7/14	30.240								H3	H5	H4	H4		X	Eulachon
36	25	7/14	30.250									(B)G1	(B)G2	G2	X	X	Genes Lake
38	26	7/16	30.260								JS1	(B)H3. 5		H3	H3	X	Eulachon
40	27	7/18	30.190								JS1	G1	(B)G2	G1	X	X	Genes Lake
42	28	7/22	30.200									M17	(B)CR1	CR1M	CR1 M	X	Cripple Cr.
44	29	7/25	30.270										(B)L2	L1		X	Clear/Lake
46	30	7/25	30.280										M4	H2	H3	X	Eulachon

**APPENDIX C. SETNET TIME, EFFORT, AND CATCH
STATISTICS, UNUK RIVER, 1994**

**Appendix C1.—Summary of daily setnet fishing times, effort and catch, by species at the Mainstem site, Unuk River, 1994.
Trends in water depth, daily high tide time and height, and comments concerning weather and fishing technique included.**

Date	Start	Stop	Total	Proc	Daily Effort	Large effort	Small chin	Chum chin	Pink	Sock	Water depth	Tide		Crew	Comments
	time	time	time	time								Time	Ht.		
16-May	1045	1730	0645	0000	0645							1743	12.7	DD/JW	River right, sunny hot, heavy mesh
16-May	1115	1800	0645	0000	0645	13.30						1743	12.7	DD/JW	River left, Commercial green net.
17-May	1020	1600	0540	0000	0540							1838	12.8	DD/JW	River right, sunny, hot, heavy mesh net
17-May	1000	1630	0630	0000	0630	12.10						1838	12.8	DD/JW	River left, sunny, hot, commercial net
30-May	0916	1532	0616	0000	0616							1809	13.9	JW	River right, overcast rain, heavy mesh
30-May	0902	1516	0614	0000	0614	12.30	0					1809	13.9	JW	River left, commercial net
03-Jun	0900	1530	0630	0000	0630		0					0931	11.1	DD/JF	River left, overcast, light rain, commercial net
03-Jun	0915	1545	0630	0000	0630	13.00	0					0931	11.1	DD/JF	River right, heavy mesh
04-Jun	0850	1604	0714	0000	0714	7.10	0					1035	11.3	JW/JF	River left, cloudy, no rain, commercial net
05-Jun						0.00									
06-Jun	1130	1620	0450	0000	0450		0					1119	14.5	DD/JW	River left, rain, heavy mesh
06-Jun	0920	1605	0645	0000	0645	11.40	0					1119	14.5	DD/JW	River right, commercial mesh
07-Jun						0.00									
08-Jun	0850	1616	0726	0000	0726		0				up	1330	13.3	JW/JF	River left, overcast, river up,
08-Jun	0834	1605	0731	0000	0731	15.00	0					1330	13.3	JW/JF	River right,
09-Jun						0.00									
10-Jun	0837	1500	0623	0000	0623		0					1441	13.8	JW/JF	River right, sunny,
10-Jun	0848	1512	0624	0000	0624	12.40	0					1441	13.8	JW/JF	River left, sunny
11-Jun	0845	1530	0645	0010	0635	6.30	1				norm	1517	14	DD/GN	River left, overcast, rain, commercial web
12-Jun						0.00							14		

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Date	Start	Stop	Total	Proc	Effort	Daily Large Small			Chum	Pink	Sock	Water depth	Tide		Crew	Comments
	time	time	time	time		effort	chin	chin					Time	Ht.		
13-Jun	1230	1645	0415	0020	0355	3.60	2						1634	14	DD/JF	River left, overcast, no rain, commercial web
14-Jun	0830	1800	0930	0015	0915	9.20	2						1715	14.1	DD/JF	River left, overcast, 1 king escaped
15-Jun	0915	1725	0810	0050	0720		4					norm	1805	14.1	KP/GN	RL, hot, rain squalls, comm gear, fish dark
15-Jun	0945	1800	0815	0255	0520	12.40	0					norm	1805	14.1	KP/GN	RR, white mesh, anchor offshore
16-Jun	0915	1800	0845	0015	0830		0					norm	1858	14.3	KP/DD	RL, heavy mesh, overcast some rain
16-Jun	0930	1750	0820	0100	0720	15.50	5					norm	1858	14.3	KP/DD	Set from root wad to shore, RL, commercial mesh
17-Jun	1055	1800	0705	0015	0650		3					norm	1957	14.7	KP/DD	Green web downstream from stump, cloudy, rain
17-Jun	1105	1800	0655	0015	0640	13.30	0					norm	1957	14.7	KP/DD	white mesh across slough
18-Jun	1010	1730	0720	0020	0700		5					norm	2058	15.3	DD/GN	Green web across slough, overcast, 1 escape
18-Jun	1030	1715	0645	0010	0635	13.40	1					norm	2058	15.3	DD/GN	White mesh downstream from stump'
19-Jun	0950	1700	0710	0010	0700		1					down	1001	12.1	KP/DD	Green mesh across slough, overcast, no rain
19-Jun	1000	1700	0700	0000	0700	14.00	0					down	1001	12.1	KP/DD	White mesh down from stump
20-Jun	0820	1540	0720	0000	0720		0						1109	12.9	DD/JF	white web across slough
20-Jun	0830	1540	0710	0020	0650	14.10	2						1109	12.9	DD/JF	commercial web down from stump, overcast
21-Jun	0820	1120	0300	0000	0300	6.00	0						1207	13.9	DM/KP	White web across slough, green downstream
22-Jun	0845	1600	0715	0015	0700	14.00	2		1		1		1259	14.7	DM/DD	white across, green down, all fish in green
23-Jun	0825	1605	0740	0020	0720		1		1				1348	15.3	DD/JF	green downstream, broken clouds
23-Jun	0835	1555	0720	0020	0700	14.20	1						1348	15.3	DD/JF	white across slough, 2 kings got out of net
24-Jun	0825	1530	0705	0000	0705		0						1433	15.6	JF/GN	green mesh across slough, partly cloudy, windy
24-Jun	0830	1535	0705	0000	0705	14.10	0						1433	15.6	JF/GN	white mesh down from stump

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Date	Start	Stop	Total	Proc	Daily Effort	Large effort	Small chin	Chin	Chum	Pink	Sock	Water depth	Tide		Crew	Comments
	time	time	time	time									Time	Ht.		
25-Jun	0830	1535	0705	0000	0705	14.10	0					up	1518	15.7	DM/GN	green across, white down, cloudy
26-Jun	0835	1535	0700	0000	0700	14.00	0					high	1601	15.5		green down, white across, overcast, windy
27-Jun	0830	1530	0700	0000	0700	14.00	0					down	1645	15.1		water down 6 in.
28-Jun	0835	1555	0720	0020	0700		2						1729	14.5	DD/JF	green web down, overcast, steady rain
28-Jun	0825	1605	0740	0010	0730	14.30	1						1729	14.5	DD/JF	white web across, 1 king escaped
29-Jun	0900	1610	0710	0010	0700	14.00	3		1				1816	13.9	DD/JF	green across, white down, all kings in green
30-Jun	0900	1600	0700	0110	0550	11.40	8		2				1905	13.5	DM/GN	gr across, wh down, all kings in green, out of tags
01-Jul	0840	1710	0830	0130	0700	14.00	7		4				1959	13.2	DD/GN	green across, white down, all kings in grn, windy
02-Jul	0900	1645	0745	0045	0700	14.00	7						0841	10.2	DM/GN	gr across, wh down, all kings in grn, windy, 1 mort
03-Jul	0855	1630	0735	0035	0700	14.00	4					low	0956	10.3	JF/GN	rain
04-Jul	0845	1600	0715	0020	0655	14.00	2					low	1059	10.8	DD/JF	2 ks in green across, white down, windy
05-Jul	0850	1705	0815	0115	0700	14.00	10	1	8			low	1150	11.5	DM/GN	3 ks in white mesh, 7 in green, overcast, rain
06-Jul	0905	1635	0730	0030	0700	14.00	5						1232	12.3	DD/JF	4 in green web across, 1 white down, rain
07-Jul						0.00						high	1310	13.1		Water too high to fish
08-Jul	1015	1725	0710	0005	0705	14.00	1						1345	13.7	GN/DH	1ks in green web, water dropping
09-Jul	0925	1650	0725	0025	0700	14.00	1		5				1420	14.3	JF/GN	green across, white down
10-Jul	0910	1620	0710	0010	0700	14.00	1		3			norm	1454	14.8	GN/JF	green across, white down, overcast, no rain, no wind
11-Jul	0900	1455	0555	0015	0540	11.20	4						1530	15.1	DM/GN	sunny, 1 mort
12-Jul	0855	1620	0725	0020	0705	14.00	4	1	13				1607	15.3	KP/RH	4ks in green down, white across, sunny

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Date	Start	Stop	Total	Proc	Effort	Daily effort	Large		Small		Chum	Pink	Sock	Water depth	Tide		Crew	Comments
	time	time	time	time			chin	chin	Chum	Pink					Time	Ht.		
13-Jul	1030	1700	0630	0040	0550	11.40	7		9						1647	15.3	DM/JF	sunny, windy
14-Jul	0835	1540	0705	0005	0700	14.00	1		3					high	1732	15.2	KP/JF	green across, white down, sunny, hot
15-Jul	0845	1555	0710	0010	0700	14.00	1	1	6						1824	15.1	DM/PM	sunny, windy, 1 jack
16-Jul	0910	1617	0707	0010	0657	14.00	2		5					drop	0703	11.7	DM/JF	cloudy, some rain
17-Jul	0915	1620	0705	0005	0700	14.00	1		7	1					0826	11.2	DM/JF	overcast, rain
18-Jul	0855	1600	0705	0005	0700	14.00	1		3					up	0950	11.5	DM/KP	overcast, rain, water up 4 in.
19-Jul	0850	1600	0710	0010	0700	14.00	1		6					drop	1101	12.3	JF/PM	overcast, little rain
20-Jul						0.00										13.4		
21-Jul	0935	1650	0715	0010	0705	14.00	4	1	10	1				drop	1249	14.4	DM/JF	sunny, some wind, water dropping, lks in white mesh
22-Jul	0900	1605	0705	0005	0700	14.00	2		6						1333	15.2	DM/JF	clear, sunny,
23-Jul						0.00										15.7		
24-Jul	0850	1610	0720	0020	0700	14.00	5		4						1453	15.9	DD/JF	clear, 3ks in green, 2ks in white web
25-Jul	0855	1600	0705	0005	0700	14.00	2		6						1531	15.8	DM/DD	cloudy, windy, one mort king
26-Jul	0905	1610	0705	0005	0700	14.00	0		3			1			1607	15.4	GN/JF	overcast, rain
27-Jul	0840	1545	0705	0005	0700	14.00	1		2						1645	14.8	GN/JF	partly cloudy, 1 mort king
28-Jul	0850	1555	0705	0005	0700	14.00	0		4			1			1723	14.1	GN/JF	overcast, rain
29-Jul	0850	1550	0700	0000	0700	14.00	0								1806	13.4	DD/GN	overcast
30-Jul						0.00												
31-Jul	0850	1350	0500	0000	0500	10.00	0		2	1					1957	12.5	DD/GN	partly cloudy
01-Aug						0.00												
Total						118	4	114	3	3								

Process Time = time cleaning or picking net. Daily effort = total effort of two nets at one site.

Appendix C2.—Summary of daily set net fishing times, effort and catch, by species at the Johnson Slough site, Unuk River, 1994 (daily high tide time and height, and comments concerning weather and fishing technique included).

Date	Start	Stop	Total	Process	Daily	Large	Small				Tide		Crew	Comments
	time	time	time	time	effort	chin	chin	Chum	Pink	Sock	Time	Height		
27-May	0905	1705	0800	0000	0800						1535	15.5		Ptly sunny
28-May	0820	1802	0942	0000	0942						1635	16.2		Cloudy, occasional rain
29-May					0000									
30-May					0000									
31-May	0900	1700	0800	0015	0745						1905	13.5		Rain, no tidal influence
01-Jun	1116	1855	0739	0000	0739						2003	13.3		Cloudy, rain, not tidal influence
02-Jun	0825	1615	0750	0000	0750						2059	13.4		Clouds, rain, no tidal effect
03-Jun	0827	1750	0923	0000	0923						0951	13.7		Clouds, rain, slight tidal effect
04-Jun	0825	1426	0601	0000	0601						1035	11.3		
05-Jun					0000									
06-Jun					0000									
07-Jun	0835	1616	0741	0000	0741						1253	12.8	JW/JF	Sunny, some clouds, no tidal effect
08-Jun					0000									
09-Jun	0822	1600	0738	0000	0738						1406	13.6	JW/JF	Partly cloudy,
10-Jun	0830	1530	0700	0000	0700						1441	13.8	DD/JF	Overcast, some rain, tidal influence
11-Jun	0830	1520	0650	0007	0643	1					1517	14	JW/JF	Overcast, rain, tidal influence
12-Jun	1000	1700	0700	0000	0700						1555	14	DD/JF	High overcast
13-Jun	1000	1800	0800	0100	0700	1					1634	14	KP/GN	Overcast, warm
14-Jun	0830	1800	0930	0010	0920			1			1717	14.1	KP/GN	Overcast, no rain, 1 chum
15-Jun	0830	1800	0930	0010	0920	1					0509	13.4	DD/JF	Sunny, windy
16-Jun					0000									

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	Start	Stop	Total	Process	Daily	Large	Small	Tide						
Date	time	time	time	time	effort	chin	chin	Chum	Pink	Sock	Time	Height	Crew	Comments
17-Jun	0930	1700	0730	0010	0720	1					0723	11.9	GN/JF	Low overcast, rain, no wind, white mesh
18-Jun	0845	1630	0745	0015	0730	1					0843	11.7	KP/JF	light rain, 1 large king escaped from white mesh
19-Jun	0900	1604	0704	0013	0651	1		2			1001	12.1	GN/JF	Overcast, green mesh
20-Jun	0820	1430	0610	0000	0610						1109	12.9	KP/GN	overcast, cool, water lowest all week.
21-Jun	0820	1130	0310	0000	0310						1207	13.9	GN/JF	partly cloudy
22-Jun	0820	1530	0710	0005	0705			1			1257	14.7	GN/JF	Clear, turned overcast, light rain.
23-Jun	0830	1645	0815	0000	0815			1			1348	15.3	DM/GN	partly sunny, water up 8", net in too much current
24-Jun					0000									
25-Jun	0915	1625	0710	0010	0700	1					1518	15.7	DD/JF	Shortened net and moved it downstream slightly.
26-Jun	0815	1535	0720	0020	0700	2					1601	15.5	DD/GN	Overcast
27-Jun	0820	1525	0705	0000	0705						1645	15.1	DD/JF	Overcast, rainy, water dropped 6" since yesterday
28-Jun	0830	1545	0715	0010	0705	2		1			1729	14.5	DM/GN	rainy, water low
29-Jun					0000									
30-Jun	0850	1550	0700	0000	0700						0622	11.8	DD/JF	Overcast, rain,
01-Jul	0830	1615	0745	0045	0700	2		7			0727	10.7	DM/JF	partly cloudy
02-Jul	0835	1610	0735	0035	0700	2	2	10			0841	10.2	DD/JF	Overcast, windy
03-Jul					0000									
04-Jul	0825	1540	0715	0000	0715			4			1059	10.8	DM/GN	Partly cloudy, windy, 1 dolly varden
05-Jul	0835	1550	0715	0015	0700	1		4			1150	11.5	DD/JF	low ceiling, light rain, 1 jack escaped
06-Jul	0845	1610	0725	0010	0715	1		5			1232	12.3	DM/GN	hard rain, no wind, water rose 6" during day
07-Jul					0000									
08-Jul					0000									
09-Jul					0000									

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Date	Start	Stop	Total	Process	Daily	Large	Small	Chum	Pink	Sock	Tide		Crew	Comments
	time	time	time	time	effort	chin	chin				Time	Height		
10-Jul	0840	1545	0705	0000	0705			7			1454	14.8	DM/DH	Overcast, calm, 3 chums in last hour on high tide
11-Jul	0820	1520	0700	0025	0635	3		8			1530	15.1	DH/JF	Clear, sunny, breezy
12-Jul	0830	1640	0810	0110	0700	14	2	27	1	1	1607	15.3	DM/GN	Sun, light wind
13-Jul	0845	1600	0715	0000	0715	3	1	14		2	1647	15.3	GN/RH	CLEAR
14-Jul	0830	1600	0730	0030	0700	3		13	1		1732	15.2	GN/PM	CLEAR
15-Jul	0840	1545	0705	0005	0700			9			1824	15.1	KP/JF	Partly cloudy, windy
16-Jul	0835	1535	0700	0005	0655	1		14	1		1923	15	KP/PM	light rain, dark king, lots "phantom hits" pinks?
17-Jul	0915	1615	0700	0000	0700			8	1		0826	11.2	KP/PM	overcast, rain, water dropping
18-Jul	0835	1550	0715	0015	0700	2	1	9	4		0950	11.5	JF/PM	overcast, calm
19-Jul					0000									
20-Jul	0835	1235	0400	0000	0400						1159	13.4	KP/JF	high clouds, partly sunny, no fish
21-Jul					0000									
22-Jul	0900	1610	0710	0010	0700	3			12	2	1333	15.2	DD/GN	Sunny, hot, released one bleeding king, 1 moose
23-Jul	0815	1525	0710	0000	0710	0	1	13	4		1414	15.7	DD/GN	Sunny, hot, calm
24-Jul	0815	1520	0705	0003	0702	1	1	13	4	1	1453	15.9	DM/GN	Sunny, water coming up
25-Jul	0815	1525	0710	0010	0700	3		9		1	1531	15.8	JF/GN	partly cloudy
26-Jul	0910	1610	0700	0000	0700		2	5	1	1	1607	15.4	DD/DM	Fog, rain
27-Jul					0000									
28-Jul	0830	1505	0635	0002	0633	1	1	1	4	3	1723	14.1		
29-Jul	0850	1550	0700	0000	0700			6	2		1806	13.4	DM/SM	Cloudy, sprinkles
30-Jul					0000									
31-Jul					0000									
Total						51	11	204	23	11				

**APPENDIX D. FISH RECAPTURED ON THE
UNUK RIVER, 1994**

Appendix D1.—Date, location, age, length, sex, and tag number of marked fish recaptured on the Unuk River, 1994.^a

Fish no.	Tagging date	Recovery date	Spag. tag	Sex	Length	Age	Recovery location	Comments ^b
35	7/14	8/14	977	f	930	1.4	Eulachon	radio present
155	7/02	8/14	842	m	935	1.4	Border Cr.	radio present
163	7/04	8/17	486	m	770	1.3	Clear Cr.	missing radio tag
23	7/12	8/19	986	f	765	1.3	Clear Cr.	radio present
25	7/12	8/19	5107	f	885	r4	Clear Cr.	
140	6/30	8/18	865	f	865	1.4	Genes Lake	radio present
37	7/14	8/18	122	f	845	1.4	Kerr Cr.	
207	7/21	8/13	488	f	775	1.3	Cripple Cr.	
	unknown	8/16	lost	f	895	1.4	Cripple Cr.	upper opercle punch
127	6/20	8/16	lost	f	845	1.4	Cripple Cr.	radio 31.852

^a Does not include one recovery (fish #180) recovered at Clear Creek on 8/25. Radio transmitter was found in a gut pile which could not be sampled for length or age.

^b Of the 10 marked fish recovered during the second event, 8 had spaghetti tags and 2 were identified by the opercle punch because the spaghetti tags had been lost. Five of the spaghetti tagged fish had also been marked with radio tags and 4 fish still had the radio tag when sampled. One of the fish missing its spaghetti tag had been radio tagged and the radio tag was still in place. The remaining fish with a lost spaghetti tag could also have lost a radio tag, but it was impossible to tell from the secondary mark, which was the same for all marked fish. The opercle punches remained visible as long as that portion of the head remained on a carcass. The fish which had lost its radio tag had been tracked to that spawning area prior to the tag being lost.

**APPENDIX E. ESTIMATED AGE COMPOSITION OF
CHINOOK SALMON ESCAPEMENT TO THE
UNUK RIVER, 1994 AND PROCEDURES
USED FOR ESTIMATION**

Appendix E1.—Estimated age composition of chinook salmon in the Unuk River escapement in 1994.

PANEL A. AGE COMPOSITION OF LARGE FISH BY SEX AND AGE CLASS												
		Age class								Total	Percent by sex	
		1.1	1.2	0.3	0.4	1.3	1.4	2.3	1.5	2.4		
Males-GN	n				1	32	28		1		62	
Males-SG	n					31	31		3		65	
Subtotal	n				1	63	59		4		127	
	%				0.8	49.6	46.5		3.1		100.0	46.3
	SE of %				0.8	4.5	4.4		1.6			4.3
	Escapement				17	1,061	994		67		2139	
	SE of esc.				18	320	302		39		616	
Females-GN	n			1		22	49				72	
Females-SG	n					46	142	1	6	2	197	
Subtotal	n			1		68	191	1	6	2	269	
	%			0.4		25.3	71.0	0.4	2.2	0.7	100.0	53.7
	SE of %			0.4		2.7	2.8	0.4	0.9	0.5		4.3
	Escapement			9		628	1,764	9	55	18	2484	
	SE of esc.			10		190	507	10	27	14	707	
Total large	n			1	1	131	250	1	10	2	396	
	%			0.2	0.4	36.5	59.6	0.2	2.7	0.4	100.0	
	SE of %			0.2	0.4	3.5	3.5	0.2	0.9	0.3		
	Escapement			9	17	1,689	2,757	9	123	18	4,623	
	SE of esc.			10	18	373	590	10	47	14	1,266	

PANEL B. AGE COMPOSITION OF SMALL MALES BY AGE CLASS												
		Age class								Total	Percent by sex	
		1.1	1.2	0.3	0.4	1.3	1.4	2.3	1.5	2.4		
Males-SG	n	16	24								40	
	%	40.0	60.0									100.0
	SE of %	7.8	7.8									0.0
	Escapement	527	790								1,316	
	SE of esc.	207	291								457	

PANEL C. AGE COMPOSITION OF TOTAL INRIVER RUN BY SEX AND AGE CLASS												
		Age class								Total	Percent by sex	
		1.1	1.2	0.3	0.4	1.3	1.4	2.3	1.5	2.4		
Males	%											58.2
	SE of %		see above									4.6
Females	%											41.8
	SE of %		see above									4.6
All fish	%	8.9	13.3	0.2	0.3	28.4	46.4	0.2	2.1	0.3	100.0	
	SE of %	2.1	2.7	0.2	0.3	2.3	3.4	0.2	0.7	0.2		
	Escapement	527	790	9	17	1,689	2,757	9	123	18	5,939	
	SE of esc.	207	291	10	18	373	590	10	47	14	1,346	

Appendix E2.—Procedures used in estimating the age composition of the escapement of chinook salmon to the Unuk River in 1994.

Many steps were required to adjust for the combination of size and sex-selective sampling we experienced on the Unuk River in 1994. In particular, gillnet samples of escapement taken in the lower Unuk River did not include small fish (males) aged 1.1 and 1.2 and samples collected on the spawning ground were biased toward the collection of females. No small females were encountered.

Because of the sampling biases, procedures were developed to estimate sex- and age-compositions of the escapement of all fish (age classes) in 1994. This was done because it can be important to consider fish aged-1.2 in assessing escapement and total returns of a brood. Such data is used for forecasting future run strength, formally or informally, and for constructing tables of total returns by brood year. It is also important to recognize that the escapement includes small fish which add genetic diversity to the stock.

In the following text and equations “small” refers to fish aged 1.1 and 1.2 and “large” refers to fish aged 0.3, 0.4, 1.3, 1.4, 1.5, 2.3, and 2.5 (all age classes sampled in 1994 are listed).

Given the sampling biases noted above, estimates of the sex and age composition of the escapement in 1994 were developed with the following assumptions: (1) *within sex* there was no difference in the age composition of *large* fish in the spawning ground and gillnet samples; (2) the gillnet sample provides an unbiased estimate of the sex composition of *large* fish in the escapement; and (3) the spawning ground sample provides an unbiased estimate of the age composition *of males* (of all ages) in the escapement.

To test assumption (1), we compared the numbers of large fish by ocean-age class captured in the spawning ground and gillnet samples by sex; the null hypothesis (no difference) was accepted for both females ($P = 0.294$; $\chi^2 = 2.445$; $df = 2$) and males ($P = 0.603$; $\chi^2 = 1.012$; $df = 2$). Assumption (2) is reasonable, since there is little difference in the size of males and females ≥ 3 within a river system in the same calendar year (Olsen 1995). Inspection of the data shows that whether or not assumption (3) was strictly met, estimates will be much less biased than the alternative, unadjusted estimates.

We estimated the age composition of the escapement in six steps: (1) estimate the total number of *large* male and female chinook salmon in the escapement using the abundance estimate (for large fish) from the mark-recapture experiment and the sex composition of large fish in the gillnet sample; (2) estimate age compositions of *large* male and female fish in the escapement (by sex) after pooling the data (for large fish) from the gillnet and spawning ground samples together by sex; (3) estimate the number of *large* male and large female fish in the escapement (by sex) using the estimated abundance and age composition estimates for large fish; (4) estimate the number of *small males* in the escapement from the proportions of small males in the spawning ground sample and the estimated total abundance of large males; (5) estimate abundance of *all* fish in the escapement *by sex and age* using the estimates for small males when age = 1.1 and 1.2, and the estimates for large fish for other age classes; and (6) calculate age compositions for the estimated escapements of all fish.

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PROCEDURES

To estimate abundance of *large* males and females in the escapement, we first estimate the fraction of each sex in the escapement of large fish ($\hat{p}_{iL\bullet}$) from the fraction in the gillnet sample (n) of large fish:

$$\hat{p}_{iL\bullet}^{gn} = \frac{n_{iL\bullet}^{gn}}{n_{\bullet L\bullet}^{gn}} \quad (1a)$$

$$v(\hat{p}_{iL\bullet}^{gn}) = \frac{\hat{p}_{iL\bullet}^{gn}(1 - \hat{p}_{iL\bullet}^{gn})}{n_{\bullet L\bullet}^{gn} - 1} \quad (1b)$$

where subscripts i, z, j denote the sex (i = F for female or M for male), size class (z = L for large or S for small fish), age class (j = 1.1 or 1.2 for small or 0.3, 0.4, 1.3,...,2.5 for large fish), a dot denotes a sum over all values of a variable, and superscript “gn” denotes the gillnet sample of escapement collected in the lower Unuk River.

The abundance of *large* males or females in the escapement was estimated

$$\hat{N}_{iL\bullet} = \hat{p}_{iL\bullet}^{gn} \hat{N}_{\bullet L\bullet} \quad (2a)$$

$$v(\hat{N}_{iL\bullet}) = v(\hat{p}_{iL\bullet}^{gn}) \hat{N}_{\bullet L\bullet}^2 + v(\hat{N}_{\bullet L\bullet}) (\hat{p}_{iL\bullet}^{gn})^2 - v(\hat{p}_{iL\bullet}^{gn}) v(\hat{N}_{\bullet L\bullet}) \quad (2b)$$

where $\hat{N}_{\bullet L\bullet}$ is the abundance of large fish from the mark-recapture experiment and variance was calculated using the formula for the product of two independent random variables (Goodman 1960).

Next, age compositions of *large* male and female fish in the escapement (p_{iLj}) were estimated by sex after pooling the gillnet and spawning ground (denoted by the superscript “sg”) samples (by sex):

$$\hat{p}_{iLj} = \frac{n_{iLj}}{n_{iL\bullet}} = \frac{n_{iLj}^{gn} + n_{iLj}^{sg}}{n_{iL\bullet}^{gn} + n_{iL\bullet}^{sg}} \quad (3)$$

where n_{iLj} is the number of large fish of sex i and age j in the pooled gillnet and spawning ground sample of all large fish ($n_{iL\bullet}$). The variance of (3) was estimated as in (1b).

Numbers of large fish in the escapement by sex and age were then calculated as in (2a and b):

$$\hat{N}_{iLj} = \hat{p}_{iLj} \hat{N}_{iL\bullet} \quad (4a)$$

$$v(\hat{N}_{iLj}) = v(\hat{p}_{iLj}) \hat{N}_{iL\bullet}^2 + v(\hat{N}_{iL\bullet}) \hat{p}_{iLj}^2 - v(\hat{p}_{iLj}) v(\hat{N}_{iL\bullet}) \quad (4b)$$

-continued-

In equation (4b) statistical independence between \hat{p}_{ilj} and $\hat{N}_{il\bullet}$ was assumed in order to use Goodman's formula. Although this is not strictly true because both gillnet and spawning samples contributed to \hat{p}_{ilj} while the gillnet sample also determines $\hat{p}_{il\bullet}^{gn}$ (part of $\hat{N}_{il\bullet}$), the dependence (covariance) in this data was found to be very small (< 5% of the variance) using Monte Carlo simulations.

For some applications we find the age composition of large fish in the escapement is of interest; estimators for this are

$$\hat{p}_{\bullet Lj} = \sum_i \hat{p}_{ilj} \hat{p}_{il\bullet}^{gn} \quad (5a)$$

$$v(\hat{p}_{\bullet Lj}) = \sum_i \left(v(\hat{p}_{ilj}) \left(\hat{p}_{il\bullet}^{gn} \right)^2 + v(\hat{p}_{il\bullet}^{gn}) \left(\hat{p}_{ilj} \right)^2 - v(\hat{p}_{ilj}) v(\hat{p}_{il\bullet}^{gn}) \right) \quad (5b)$$

where statistical independence between \hat{p}_{ilj} and $\hat{p}_{il\bullet}^{gn}$ was again assumed in order to use Goodman's formula. As noted above this is not strictly true because both gillnet and spawning samples contributed to \hat{p}_{ilj} ; however, as noted above this dependence was very small in this experiment.

To obtain estimates which include *small* fish, we first estimated the abundance of small males (fish aged 1.1 and 1.2 years; recall that no small females were sampled) in the escapement, using the relationships

$$\hat{N}_{MS\bullet} = \hat{N}_{ML\bullet} \left(\frac{1}{\hat{p}_{M\bullet x}^{sg}} - 1 \right) \quad x = \text{all ages except 1.1 and 1.2} \quad (6a)$$

$$v(\hat{N}_{MS\bullet}) \approx v\left(\frac{1}{\hat{p}_{M\bullet x}^{sg}}\right) \hat{N}_{ML\bullet}^2 + v(\hat{N}_{ML\bullet}) \left(\frac{1}{\hat{p}_{M\bullet x}^{sg}} - 1 \right)^2 - v\left(\frac{1}{\hat{p}_{M\bullet x}^{sg}}\right) v(\hat{N}_{ML\bullet}) \quad (6b)$$

where $\hat{p}_{M\bullet x}^{sg}$ is the proportion of the spawning ground sample of male fish not aged at either 1.1 or 1.2 years (i.e., the proportion of large fish among males in the spawning grounds sample) and the variance was calculated as in equation (2b). The variance of $1/\hat{p}_{M\bullet x}^{sg}$ in equation (6b) was evaluated using the Delta method (Seber 1982):

$$v\left(\frac{1}{\hat{p}_{M\bullet x}^{sg}}\right) \approx \frac{v(\hat{p}_{M\bullet x}^{sg})}{\left(\hat{p}_{M\bullet x}^{sg}\right)^4} \quad (6c)$$

where $v(\hat{p}_{M\bullet x}^{sg})$ was estimated as in equation (1b).

The number of *small* fish by age class was calculated

$$\hat{N}_{MSj} = \hat{N}_{MS\bullet} \hat{p}_{MSj}^{sg} \quad j = 1.1 \text{ or } 1.2 \quad (7a)$$

-continued-

$$v(\hat{N}_{MSj}) = v(\hat{p}_{MSj}^{sg}) \hat{N}_{MS\bullet}^2 + v(\hat{N}_{MS\bullet}) \left(\hat{p}_{MSj}^{sg} \right)^2 - v(\hat{p}_{MSj}^{sg}) v(\hat{N}_{MS\bullet}) \quad (7b)$$

where

$$\hat{p}_{MSj}^{sg} = \frac{n_{MSj}^{sg}}{n_{MS\bullet}^{sg}} \quad (7c)$$

is the proportion of male fish aged 1.1 or 1.2 years in the spawning ground sample of *small* fish (fish aged 1.1 and 1.2) and $v(\hat{p}_{MSj}^{sg})$ was estimated as in equation (1b). An assumption of statistical independence between $\hat{N}_{MS\bullet}$ and \hat{p}_{MSj}^{sg} was used to estimate $v(\hat{N}_{MSj})$ using Goodman's formula, but this is not strictly true since the spawning ground sample contributed to both \hat{p}_{MSj}^{sg} and $\hat{p}_{MS\bullet}^{sg}$ (part of $\hat{N}_{MS\bullet}$). However, Monte Carlo simulations showed that in this experiment, variance was accurately calculated (within $\pm 5\%$ of simulated values) with Goodman's formula.

The estimated abundance of *all* fish in the *escapement by sex and age* ($\hat{N}_{i\bullet j}$) are the estimates for small males when age = 1.1 and 1.2 (no small females were captured), and the estimates for large fish otherwise.

Sex composition of the *escapement* is

$$\hat{p}_{i\bullet\bullet} = \frac{\hat{p}_{iL\bullet}^{gn} + \hat{p}_{iL\bullet}^{gn} \hat{X}_i}{1 + \hat{p}_{ML\bullet}^{gn} \hat{X}_M} \quad (8a)$$

where $X_i = (1 / \hat{p}_{i\bullet x}^{sg} - 1)$; note that the second term in the numerator vanishes when sex i equals females because $\hat{p}_{F\bullet x}^{sg} = 1$. Variance was estimated using the delta method:

$$v(\hat{p}_{i\bullet\bullet}) \approx v(\hat{p}_{iL\bullet}^{gn}) \partial' (\hat{p}_{iL\bullet}^{gn})^2 + v(\hat{X}_i) \partial' (\hat{X}_i)^2 \quad (8b)$$

where the notation $\partial' (p_{iL\bullet}^{gn})^2$ refers to the square of the partial derivative (∂') of the function $[p_{i\bullet\bullet}]$ with respect to the variable $p_{iL\bullet}^{gn}$. Monte Carlo simulations were used to verify that equation (8b) provided a good approximation (within $\pm 5\%$) to the true variance in this experiment.

Similarly, age composition of the *escapement* was estimated

$$\hat{p}_{\bullet\bullet j} = \frac{\hat{p}_{MLj} \hat{p}_{ML\bullet}^{gn} + \hat{p}_{FLj} (1 - \hat{p}_{ML\bullet}^{gn})}{1 + \hat{p}_{ML\bullet}^{gn} \hat{X}_M} \quad j \neq 1.1, 1.2 \quad (9a)$$

or

$$\hat{p}_{\bullet\bullet j} = \frac{\hat{p}_{MSj}^{sg} \hat{p}_{ML\bullet}^{gn} \hat{X}_M}{1 + \hat{p}_{ML\bullet}^{gn} \hat{X}_M} \quad j = 1.1, 1.2 \quad (9b)$$

-continued-

and variance was estimated using the delta method:

$$\begin{aligned}
 v(\hat{p}_{..j}) \approx & v(\hat{p}_{MLj}) \partial' (\hat{p}_{MLj})^2 + v(\hat{p}_{ML.}^{gn}) \partial' (\hat{p}_{ML.}^{gn})^2 + v(\hat{p}_{FLj}) \partial' (\hat{p}_{FLj})^2 + \\
 & v(\hat{X}_i) \partial' (\hat{X}_i)^2 + 2 [\text{cov}(p_{MLj}, p_{ML.}^{gn}) \partial' (p_{MLj}) \partial' (p_{ML.}^{gn}) + \\
 & \text{cov}(p_{MLj}, p_{FLj}) \partial' (p_{MLj}) \partial' (p_{FLj}) + \text{cov}(p_{MLj}, X_M) \partial' (p_{MLj}) \partial' (X_M) + \\
 & \text{cov}(p_{FLj}, X_M) \partial' (p_{FLj}) \partial' (X_M) + \text{cov}(p_{ML.}^{gn}, p_{FLjM}) \partial' (p_{ML.}^{gn}) (\partial' p_{FLj})]
 \end{aligned} \tag{9c}$$

for $j \neq 1.1, 1.2$; also,

$$\begin{aligned}
 v(\hat{p}_{..j}) \approx & v(\hat{p}_{MSj}^{sg}) \partial' (\hat{p}_{MSj}^{sg})^2 + v(\hat{p}_{ML.}^{gn}) \partial' (\hat{p}_{ML.}^{gn})^2 + v(\hat{X}_M) \partial' (\hat{X}_M)^2 + \\
 & 2 \text{cov}(p_{MSj}^{sg}, X_M) \partial' (p_{MSj}^{sg}) \partial' (X_M)
 \end{aligned} \tag{9d}$$

for $j = 1.1, 1.2$. Monte Carlo simulations were used to estimate the true variances, and compare them to estimates made from equations (9c) and (9d) *with the covariance terms omitted*; results using equation (9c) accurately estimated (within $\pm 5\%$) simulated variances, but results from equation (9d) underestimated simulated values by about 15%. Thus, estimates from the simulations were reported in lieu of those from equation (9d).

RESULTS

The inriver run (immigration) of chinook salmon in the Unuk River in 1994 comprised mostly age-1.3 fish (1,689; SE = 373) and age-1.4 fish (2,757; SE = 590). The estimated population for the inriver run was 5,939 (SE = 1,346) chinook salmon, estimated from 4,623 (SE = 1,266) fish from the mark-recapture experiment for large fish plus as estimated 1,316 (SE = 998) small fish (ages 1.1 and 1.2). The reader is cautioned that the estimate for small fish was not directly estimated, but was calculated from the estimate for the large fish and age composition of males on the spawning grounds.

Among large fish, the estimated sex composition was 46.3% (SE = 4.3%) males and 52.7% (SE = 4.3%) females; the estimated abundance by sex was 2,139 (SE = 616) males and 2,484 (SE = 707) females. The estimated age composition for large fish (sexes combined) was 37% (SE = 3.5%) age-1.3 fish, 60% (SE = 3.5%) age-1.4 fish and 3% (SE = 0.9%) age-1.5 fish. Among large males, fish were almost evenly split between age-1.3 fish (50%; SE = 4.5%) and age-1.4 fish (47%; SE = 4.4%). Among large females, age-1.3 fish were 25% (SE = 2.7%) and age-1.4 fish were 71% (SE = 2.8%) of the estimated total.

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Estimated abundance of small fish was 1,316 (SE = 457); sex composition was 100% males—no females were encountered in either set of age samples. Age-1.1 fish constituted 40% (SE = 7.8%) and age-1.2 60% (SE = 7.8%) of the estimated small fish. As this composition was estimated from spawning grounds sampling using methods which may have been biased towards larger fish, the number of small fish may have been underestimated.

Total population was estimated at 5,939 (SE = 1,346) chinook salmon, comprising 58% (SE = 4.6%) males and 42% (SE = 4.6%) females. For sexes combined the inriver run comprised an estimated 9% (SE = 2.1%) age-1.1 fish, 13% (SE = 2.7%) age-1.2 fish, 28% (SE = 2.3%) age-1.3 fish, 46% (SE = 3.4%) age-1.4 fish and 2% (SE = 0.7%) age-1.5 fish; ages 0.3, 0.4, 2.3 and 2.4 constituted less than 1% of the population.
